AD NUMBER

AD900401

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies only; Administrative/Operational Use; FEB 1972. Other requests shall be referred to Office of Supersonic Transport Development, Washington, DC 20590.

AUTHORITY

FAA ltr, 26 Apr 1977

Report No. FAA-SS-72-41

SST Technology Follow-On Program—Phase I

A SUMMARY OF THE SST NOISE SUPPRESSION TEST PROGRAM

The Boeing Company
Commercial Airplane Group
P.O. Box 3707
Seattle, Washington 98124

D6-60241
February 1972

FINAL REPORT
Task 4

Approved for U.S. Government only. Transmittal of this document outside of U.S. Government must have prior approval of the Office of Supersonic Transport Development.

Prepared for

FEDERAL AVIATION ADMINISTRATION
Office of Supersonic Transport Development
800 Independence Avenue, S.W.
Washington, D.C. 20590

18 17

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FAA-SS-72-41	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle SST TECHNOLOGY FOLLOW-ON PROGRAM—PHASE I, A SUMMARY OF THE SST JET NOISE SUPPRESSION TEST PROGRAM		5. Report Date February 15, 1972
		6. Performing Organization Code
7. Author(s) C. P. Wright, D. B. Morden, C. D. Simcox		8. Performing Organization Report No. D6-60241
9. Performing Organization Name and Address The Boeing Company Commercial Airplane Group P.O. Box 3707 Seattle, Washington 98124		10. Work Unit No.
		11. Contract or Grant No. DOT-FA-SS-71-12
12. Sponsoring Agency Name and Address Federal Aviation Administration Office of Supersonic Transport Development 800 Independence Avenue, S.W. Washington, D.C. 20590		13. Type of Report and Period Covered Final Report, on Task 4
		14. Sponsoring Agency Code

15. Supplementary Notes

11 15 Feb 72 12 540p.

16. Abstract

Supersonic aircraft require propulsion systems that are significantly different from those for present subsonic aircraft. The higher jet velocity of the supersonic aircraft engines will generate more noise during the actual takeoff run than conventional jet transport engines. An applied research program was conducted at The Boeing Company from February 1966 through March 1971 to investigate jet nozzle systems which will suppress jet noise levels from the supersonic transport with minimal thrust loss. These efforts applied to the two prototype supersonic transports being developed at that time as well as the commercial version of the SST that was to follow. The research program indicated that 12 to 20 PNdB noise suppression can be attained with less than 10% thrust loss by using multielement jet nozzle concepts. This report summarizes the test results pertaining to suppressor nozzle noise and thrust characteristics.

17. Key Words	18. Distribution Statement
Supersonic transport Jet noise suppression Supersonic jet noise Nozzle thrust performance Nozzle systems	Approved for U.S. Government only. Transmittal of this document outside of U.S. Government must have prior approval of the Office of Supersonic Transport Development.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
		530	

Form DOT F 1700.7 (8-69)

390145

CONTENTS

CONTENTS (Concluded)

FIGURES

FIGURES—Concluded

TABLES

SYMBOLS

A_B	nozzle base area = A_F (AR - 1)
A_{BID}	ejector inlet ventilating flow area
A_{BID}/A_B	ejector ventilation parameter
A_E	nozzle exit area (convergent-divergent nozzle)
A_F	nozzle flow area
AR	ratio of total nozzle area to flow area
A_S	tube array physical ventilation flow area between outer-row tubes
A_S/A_B	ventilation parameter
A_T	ejector cross-sectional flow area at throat station
A_8	nozzle area at the exit plane
A^*	nozzle throat area
BID	ejector blow-in door to allow admission of ambient air
C_D	nozzle discharge coefficient (equals measured weight flow divided by ideal weight flow of physical flow area at prescribed nozzle total pressure and total temperature)
C_{Fg}	gross thrust coefficient (equals measured nozzle thrust divided by ideal thrust of *measured* weight flow at prescribed nozzle total pressure and total temperature $F/(W_{act}V_{IP}/g)$)
D_B	nozzle base drag, lb
D_E	diameter of ejector exit or diameter of ejector for constant-area ejectors
D_P	nozzle diameter to outside of baseplate
D_T	ejector throat diameter
EPNL	effective perceived noise level, EPNdB
F_I	ideal thrust of given nozzle weight flow at prescribed nozzle total pressure and total temperature, lb

g	universal gravitational constant
L	ejector length excluding inlet lip
L_T	exposed tube length from baseplate to tube exit
M_e	tube exit Mach number
M_g	Mach number of the fully expanded flow
N_o	number of tubes in outer row
OASPL	overall sound pressure level (45 to 11,200 Hz, full scale), dB
OASPL (average)	averaged values of OASPL from two or more microphone locations, dB
P_B	average base pressure on baseplate
P_B/P_V	nozzle base pressure ratio for shrouded configurations
P_B/P_∞	nozzle base pressure ratio (no ejector installed)
P_{LIP}	static pressure acting on internal surface of ejector inlet lip
PNL	perceived noise level, PNdB
P_T	nozzle total pressure
P_T/P_∞	nozzle pressure ratio
P_V	local ventilating air static pressure surrounding multitube array for shrouded configurations
P_∞	freestream static pressure
R	gas constant
RC	round convergent (nozzle)
SPL	sound pressure level, dB re: 0.0002 dynes/cm^2
TSEN	two-stage ejector nozzle
T_T	nozzle gas total temperature, °F
T_8	nozzle gas total temperature at the exit plane, °F

V_{IP}	ideal fully expanded primary jet velocity at prescribed nozzle total pressure and total temperature, fps
W_A	measured primary airflow rate, lb/sec
W_{act}	measured primary nozzle gas flow rate, lb/sec ($W_A + W_f$)
W_f	fuel flow rate, lb/sec
γ	gas specific heat ratio
θ	half angle of spoke apex, deg

1.0 INTRODUCTION

The supersonic transport jet noise reduction efforts described in this document encompass the period from February 1966 through March 1971. During these 5 years, The Boeing Company and the General Electric Company were developing two prototype SST aircraft and engines under FAA contracts.

Both Boeing and General Electric conducted applied research on the problem of suppressing SST propulsion radiated acoustic noise. Only the results of the Boeing program will be presented in this review.

Initially, the Boeing research program was divided into a low noise-suppression effort to investigate ways of obtaining at least 5 PNdB sideline suppression and a high noise-suppression effort to obtain 12 to 20 PNdB sideline suppression with 10% or less thrust loss. About 5 PNdB suppression was deemed necessary to meet 1966 requirements of $\leq$116 PNdB maximum noise levels at the 1500-ft sideline for the prototype SST. Higher noise suppression was considered necessary for the commercial version of the SST to:

- Achieve community noise standards under the flightpath comparable to subsonic intercontinental aircraft in the same production time period

- Achieve sideline noise reduction such that, at a distance of 1 nmi to the side of any international runway, the SST would be as quiet as the existing subsonic jets

It was believed that these objectives would be technically feasible by early 1978 and were consistent with proposed airport noise regulations and land use of 1966.

The Federal Aviation Administration (on November 3, 1969) issued *Noise Standards: Aircraft Type Certification* referred to as FAR 36. These noise standards became the goal for the production SST jet noise suppression effort. At takeoff, the perceived noise level at the 0.35-nmi sideline was not to exceed 108 EPNdB, cutback noise underneath the aircraft 3.5-nmi from the start of the takeoff roll was not to exceed 108 EPNdB, and approach noise at a point 1 nmi from the threshold was not to exceed 108 EPNdB.

The SST jet noise suppression program was a joint effort of the aircraft noise, aerodynamics, design, and propulsion staffs of the Commercial Airplane Group. The techniques of supersonic jet noise suppression had to be established, mindful of other considerations affecting aircraft reliability and economics. Any jet noise suppression hardware applied to the engines must be retracted when the aircraft is clear of the community to avoid penalizing flight efficiency during climb and cruising flight. Originally, suppressor nozzle hardware had to be subjected to an afterburner primary gas environment approaching 3000° F. This required an investigation into materials and methods of cooling. Nozzle thrust losses had to be determined and methods for minimizing these losses ascertained.

1.1 LOW NOISE-SUPPRESSION (5 PNDB) PROGRAM

The purpose of this test program was to develop a jet noise suppressor concept for the SST turbojet engine that would allow the prototype airplane to take off with maximum available thrust and not to exceed the 116-PNdB, 1500-ft sideline noise objective set by the FAA. It was calculated that a minimum of 5 PNdB of noise suppression with respect to a standard nozzle configuration would be required.

The initial nozzle configurations considered to achieve the 5-PNdB suppression were determined from a review of past noise studies. Particular emphasis was placed on a review of model suppressor nozzle tests conducted by Boeing, General Electric, and P&WA, references 1, 2, 3, and 4. Nozzle noise suppressor systems were selected that were considered adaptable to the prototype SST engine and would provide the desired amount of noise suppression.

Suppressor nozzle hardware was designed and manufactured. Model-scale nozzle testing was conducted to determine noise-suppression characteristics, and the more promising configurations were modified to determine optimum relationships between physical parameters and jet noise suppression.

A parallel program to study the thrust, drag, and weight penalties associated with selected suppressor systems was conducted by the Propulsion staff (ref. 5). The suppressor nozzle configurations that provided at least 5 PNdB suppression and were best suited to current SST design were constructed and tested on a J-75 engine to confirm model-scale test results. The model-scale 5-PNdB test program is described in references 6 and 7. The large-scale 5-PNdB test program is described in references 8, 9, and 10.

1.2 HIGH NOISE-SUPPRESSION (20 PNDB) PROGRAM

The high noise-suppression program proposed to develop a jet noise suppressor concept that could be applied to the production (or commercial) SST airplane. It was predicted that 12- to 20-PNdB sideline jet noise suppression was necessary at the sideline measuring point during lift-off to meet FAA community noise requirements. The jet noise suppressor system should not exact more than 10% thrust loss and still be compatible with cruise stowage requirements. Jet noise suppressor nozzles attaining a PNdB suppression/percent-thrust-loss ratio greater than unity were considered candidates for a jet noise suppression system.

The applied research program to determine suppressor nozzle noise characteristics was primarily oriented to subjective considerations, e.g., PNdB levels at the 1500-ft sideline. A secondary consideration was the investigation of noise spectra, undistorted by atmospheric propagation anomalies, to determine the major influences of jet configuration on acoustic signatures. Initially, there was very little information available concerning jet noise suppression systems applicable to the SST and GE4 engine. The relatively high nozzle pressure ratio and total temperature of the primary flow common to the GE4/J5P engine was beyond the consideration of jet noise research programs conducted previously. At the onset of the SST high noise-suppression program, the groups involved in the development of a commercial version SST jet noise suppression system (e.g., Boeing Acoustics, Aerodynamics, Propulsion, Project Design, and Thermal Environment staffs) had to establish their particular technologies. This required development of facilities to acquire test data; construction of test hardware;

and establishment of the methods, computer routines, and other software items necessary. An integrated effort was established between the technical groups whenever development of a design concept was considered.

The general technical approach that was applied to solve the SST jet noise problem was as follows:

- Review previous noise suppressor data.
- Design, fabricate, test, and analyze new suppressor model configurations having high suppression potential.
- Establish suppressor acoustic and performance characteristics of basic suppressor concepts as a function of key variables.
- Conduct suppressor element thermal environment and cooling tests to establish required design criteria compatible with afterburning operation.
- Conduct design implementation studies to incorporate desired suppressor characteristics and define resulting installation penalties.
- Conduct engine-cycle and airplane-installation studies to define optimum compromise between noise level and airplane performance.
- Design, fabricate, test, and analyze suppressor configurations that reflect above study results.
- Conduct large-scale tests to verify small-scale results.
- Design, fabricate, and test large-scale demonstrator suppressor nozzles meeting program objectives and representing best overall compromise between noise level and airplane performance.

The first suppressor nozzle configurations tested were multitube and multispoke hardware from earlier test programs. These nozzles, designated MPP or MAE, were eighth-scale JT3/C4 (or C6) engine suppressor nozzle concepts. Testing was limited to a maximum total temperature of 1100°F. At a nozzle pressure ratio of 3.0, these nozzles provided 7 to 11 PNdB suppression at 1500-ft sideline. The results were encouraging enough to warrant a parametric study of spoke- and tube-type nozzle configurations to determine the prime variables associated with jet noise suppression.

2.0 JET NOISE TEST FACILITIES AND TECHNIQUES

Most of the SST jet noise suppression program model-scale testing was accomplished at the Boeing Annex D and hot-nozzle test facility (HNTF) in Seattle. Throughout the program, facilities and measurement techniques were improved for acquiring and reducing data, increasing the dynamic range of the gas generators, and controlling acoustic interference anomalies such as ground reflection interference and sources of noise interference.

The same improvements occurred at the full-scale test facilities. Initial testing was done on an afterburning YJ-75 turbojet engine at the North end of Boeing Field in Seattle. The Boeing Company program to minimize noise for neighboring communities led to development of Boeing's Boardman, Oregon site as a research facility for the study of aircraft propulsion system noise reduction. Full-scale testing of SST jet noise suppressor concepts at Boardman used the YJ-75 and J-93 turbojet engines. Unfortunately, an engine capable of the high pressure ratios with high total temperatures equivalent to the proposed GE4 engine conditions at takeoff had never been developed. Therefore, full-scale testing was more representative of SST cutback engine conditions and was used more to verify the model-scale suppressor test results and scaling techniques employed. A 36-spoke nozzle tested both full scale and model scale showed very good agreement in jet noise characteristics (see ref. 11). Full-scale test anomalies, e.g., ground reflection interference and engine machinery noise interference, are much more difficult to control compared to model-scale tests when jet noise suppression is the object of investigation. As a research tool, the model-scale test facility at this time is more versatile and yields higher quality and quantity of data at lower cost. Full-scale testing of an engine/suppressor nozzle system is important to determine the conglomerate acoustic signature of the propulsion system from individual sound sources, e.g., jet noise, turbomachinery noise, fan noise, engine casing noise, etc., in the final analysis.

2.1 MODEL-SCALE

2.1.1 Annex D

The hot-gas test facility is located at Annex D in the Boeing Plant II complex at Seattle, Washington. The facility was designed to test eighth-scale nozzle hardware with a flow area of 13.2 sq in. Pressure ratios of 7.0 and temperatures of 2500° F are possible. A 6-in. flow duct and limited air supply of 16 lb/sec restricted the size of nozzles tested. The hot-gas equipment, similar to a scaled version of an afterburning J-47 engine, is mounted in an outdoor arena on the north side of Annex D. Controls for regulating gas temperature and total pressure, acoustic data recording equipment, and performance data recording equipment are located within Annex D.

Figure 1 shows the acoustic test arena. The arena is bounded by a slanted-wall fence to reduce the noise levels in adjacent work spaces. An anemometer/wind vane set in the test arena with a readout in the control room is monitored during the recording of acoustic data to keep wind-induced acoustic propagation anomalies within prescribed limits. A closed-circuit television system provides visual monitoring of test hardware. The floor of the acoustic test arena is paved with concrete resulting in a "hard" acoustical surface. The hot-gas flow pipe axis or jet axis is horizontal and 20 in. above the arena floor.

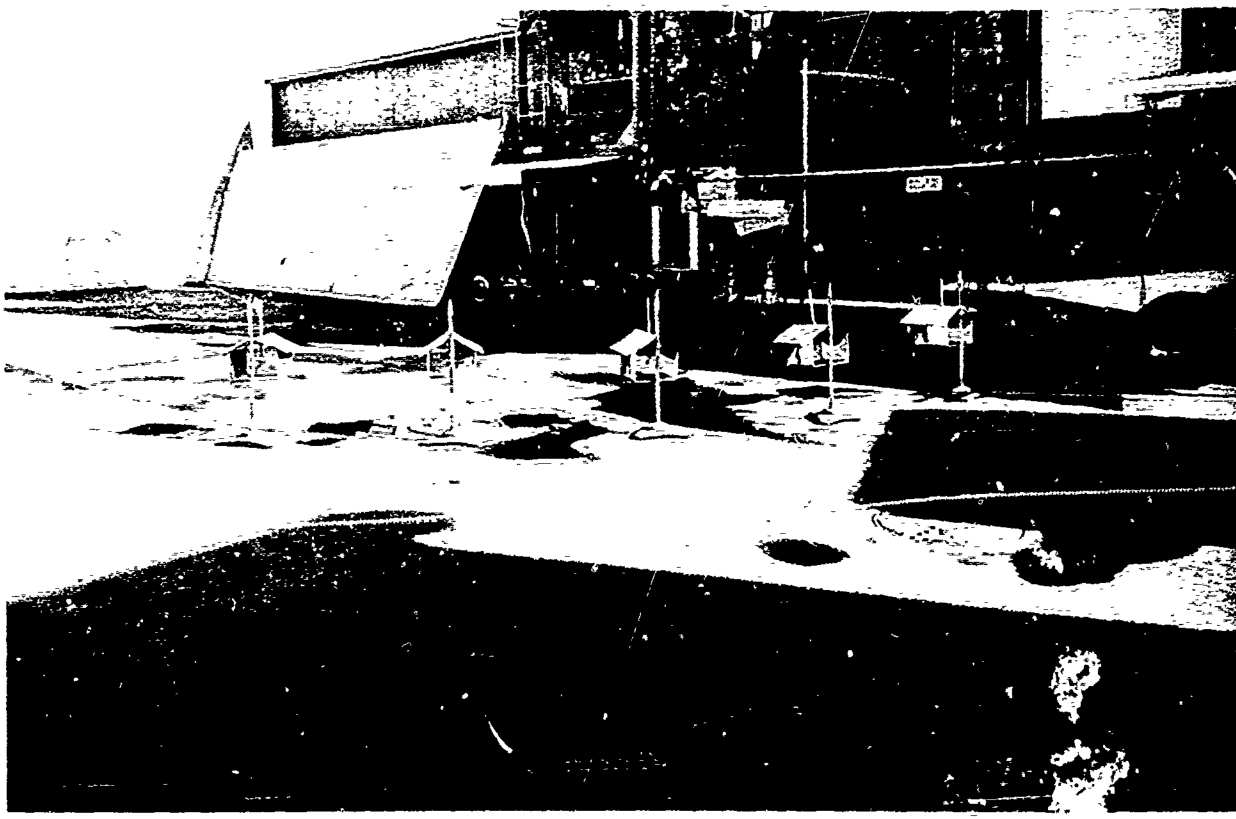


FIGURE 1.—ANNEX D HOT-GAS TEST FACILITY, ACOUSTIC ARENA (1968)

Initially, the microphones were placed 20 in. above the arena floor on a 25-ft arc centered at the nozzle exit. In eighth-scale nozzle tests, 25 ft was equivalent to 200 ft in full scale. This test setup introduced a ground reflection interference anomaly that distorted the measured spectrum.

Another microphone arrangement used the 25-ft polar arc layout except that the microphone was located close to the arena floor. This situation was designed to make use of pressure "doubling" at the air/ground interface. Theoretically, the noise spectrum measured at the acoustically hard ground surface will be 6 dB higher than the free-field noise levels. Subtracting 6 dB from the measured noise levels should provide the free-field spectrum level. This advancement facilitated spectrum analysis techniques The irregularities of the arena floor relative to the wave length of the acoustic noise recorded introduced diffraction anomalies that caused some distortion, notably in the high-frequency portion of the spectrum.

An overhead or vertical-plane microphone arrangement was installed during 1968. Microphones were located at 10° intervals from 40° to 80° on a 25-ft polar arc. The jet turbulence was used to shield the microphones from the ground-reflected noise. This allowed direct measurement of the free-field jet noise with no adjustments to the spectrum necessary. Later it was determined that the low frequencies diffracted around the jet causing abnormally high noise levels in that portion of the spectrum. Installation of a 2-in.-thick fiberglass blanket on the ground underneath the jet eliminated the low-frequency ground-reflection interference.

2.1.1.1 Internal Flow and Performance Instrumentation

Nozzle gas pressures were set by the facility operator with an open mercury manometer indicator with an accuracy of ±0.2 in. Hg. Gas total temperature was measured with a platinum, 10% rhodium thermocouple, accurate to within 60° at 3000° R. An ASME flow nozzle upstream of the burner was used to measure air weight flow. Fuel flow to the burner was measured by a Potter flow meter accurate to within ±0.5%. A 1000-lb Baldwin loadcell was used to measure thrust. The accuracy of thrust measurements was never certified but is believed to be within ±0.5% to ±2%. A schematic of the burner and thrust rig is shown in figure 2. Photographs of the burner, burner control panel, and scanner printout system are shown in figures 3, 4, and 5. The values printed out by the scanner instrument system were thrust, fuel flow, fuel pressure, fuel temperature, air temperature, flow nozzle pressures, exhaust nozzle total pressure, and exhaust nozzle total temperature.

A complete description of the Annex D, test cell 1 hot-gas supply system can be found in references 12 and 13.

2.1.1.2 Acoustic Instrumentation

A block diagram of the acoustic data acquisition system is shown in figure 6 (from ref. 7). Four to eight microphone systems were used, depending on the test requirements. Each microphone system was calibrated with an electrostatic actuator and a frequency recorder from 20 Hz to 200 kHz. An electrical insert voltage calibration was performed on the remainder of the data acquisition system using an automatic frequency response recorder from 20 Hz to 200 kHz.

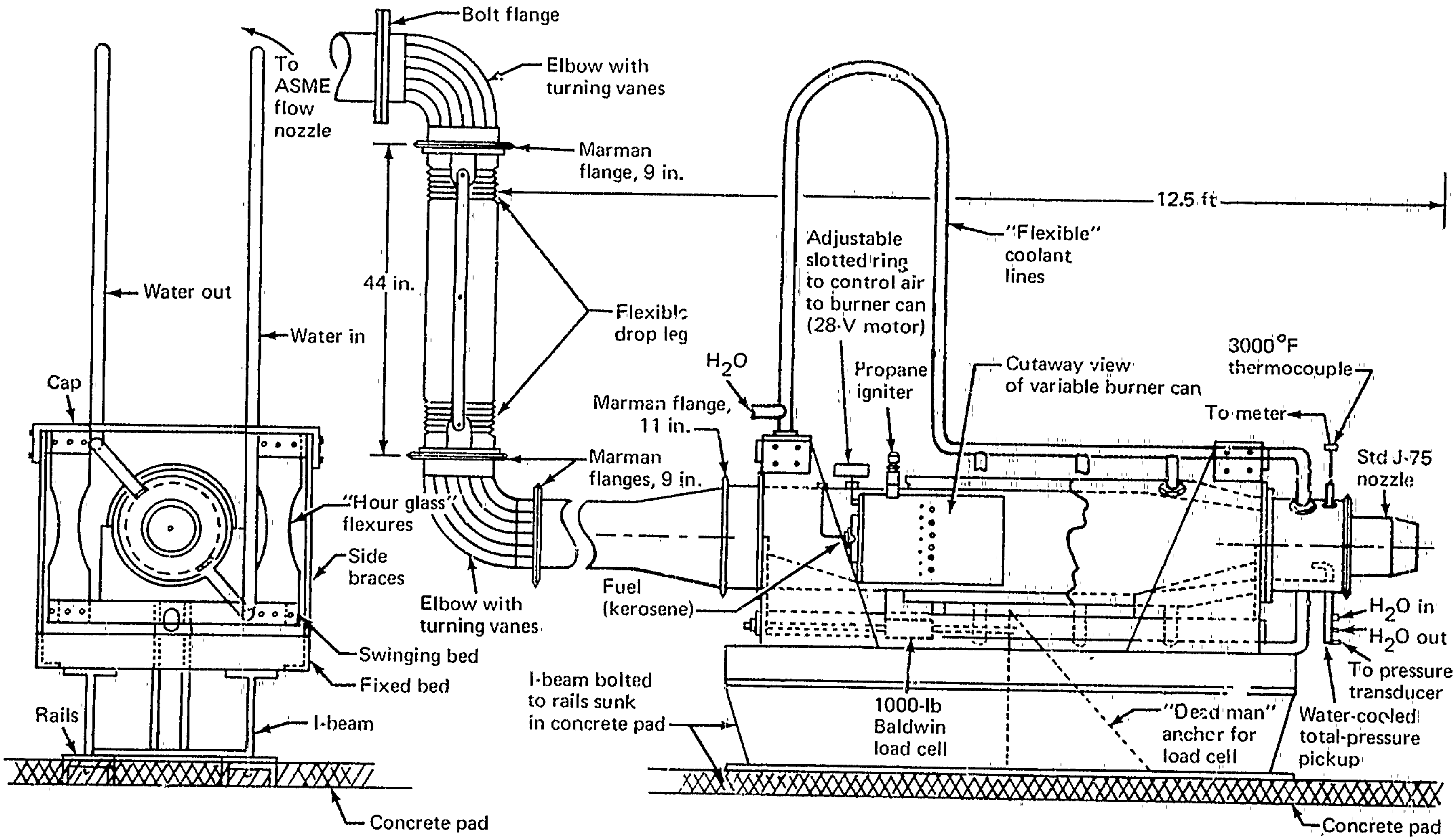


FIGURE 2.—THRUST RIG

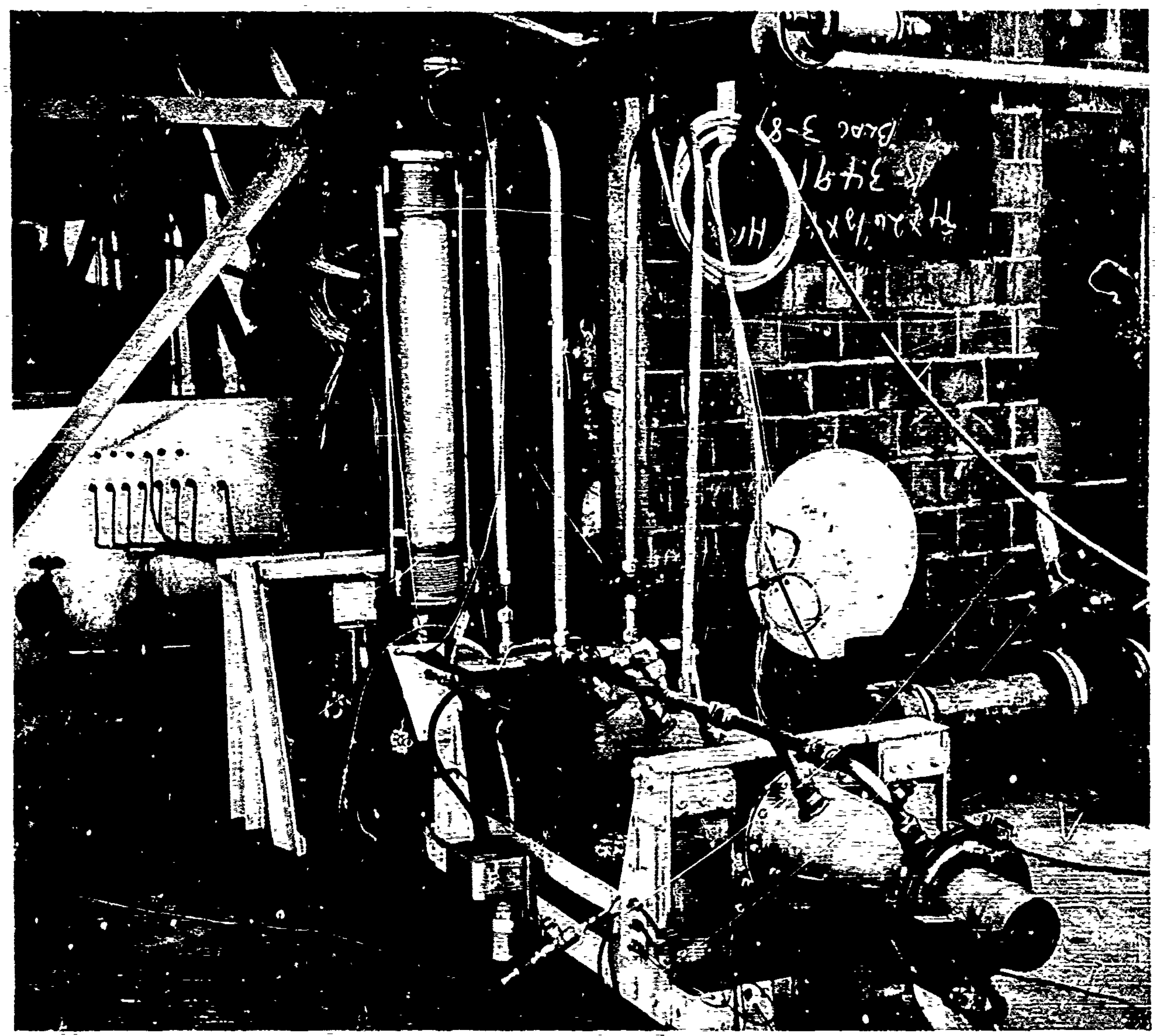


FIGURE 3.—ANNEX D HOT-GAS TEST FACILITY, BURNER AND THRUST RIG (1968)

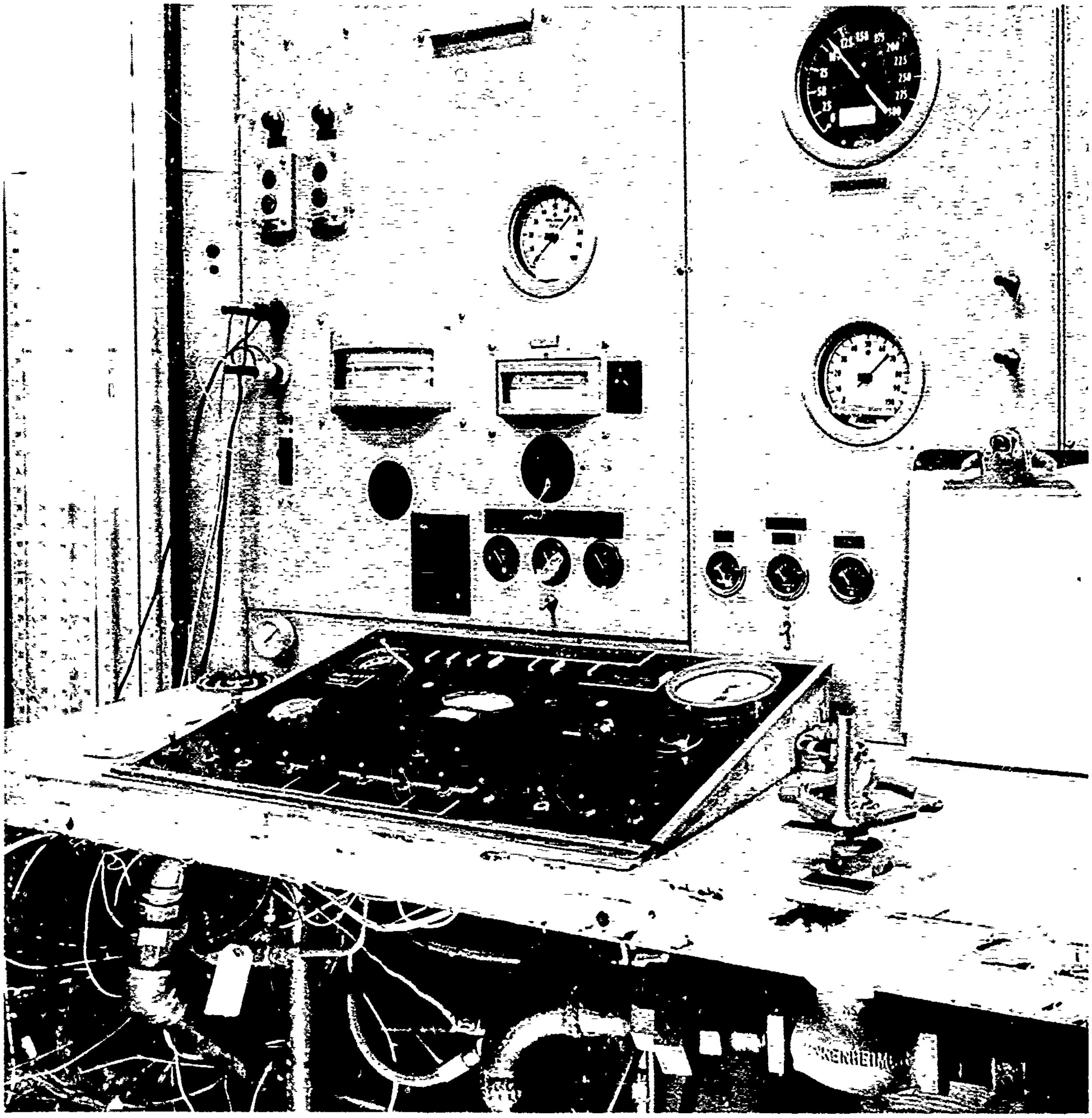


FIGURE 4.—ANNEX D HOT-GAS TEST FACILITY, BURNER CONTROL PANEL (1968)

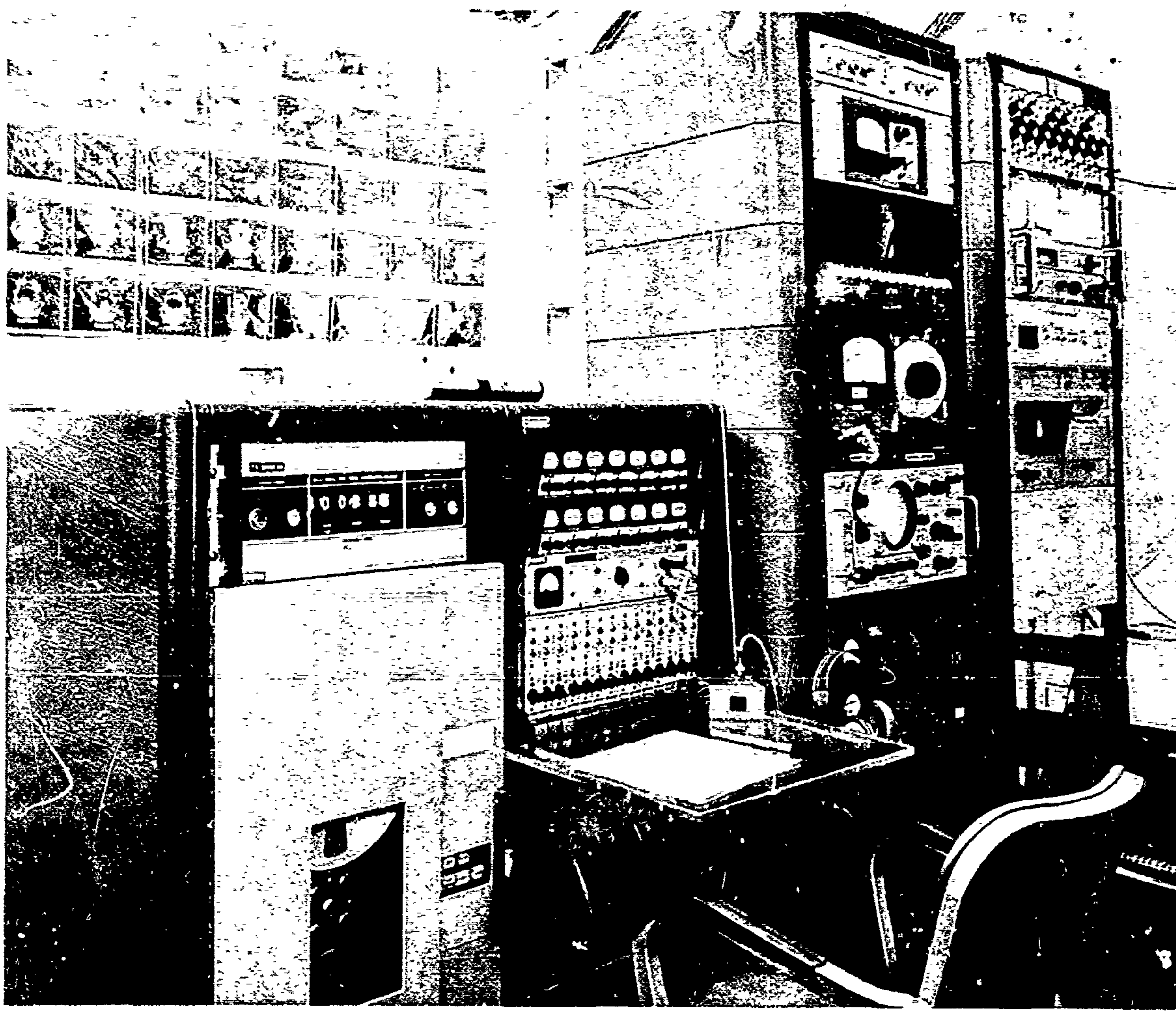
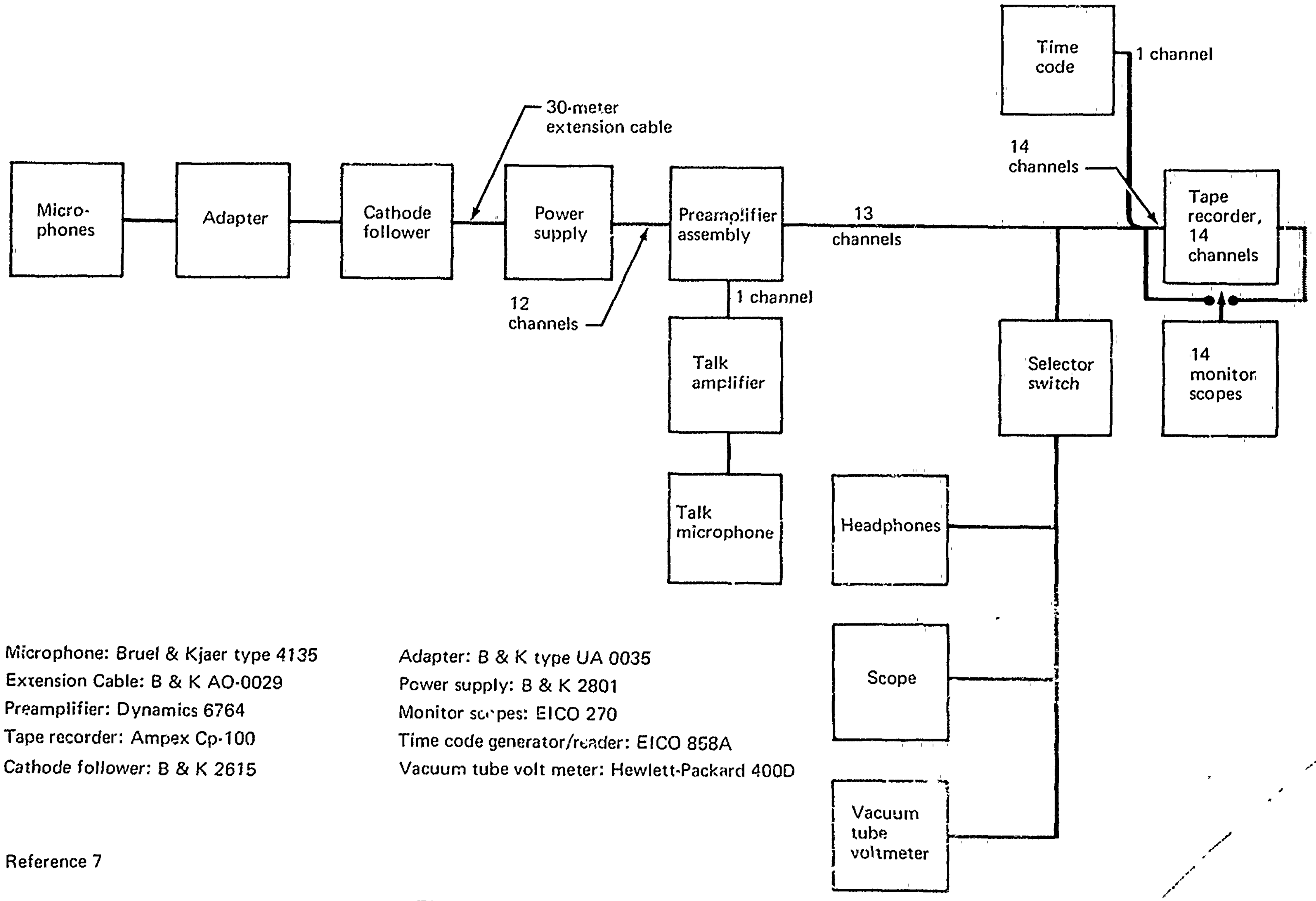


FIGURE 5.–ANNEX D HOT-GAS TEST FACILITY, ACOUSTIC RECORDING AND SCANNER PRINTOUT EQUIPMENT (1968)



Microphone: Bruel & Kjaer type 4135
Extension Cable: B & K AO-0029
Preamplifier: Dynamics 6764
Tape recorder: Ampex Cp-100
Cathode follower: B & K 2615

Adapter: B & K type UA 0035
Power supply: B & K 2801
Monitor scopes: EICO 270
Time code generator/reader: EICO 858A
Vacuum tube volt meter: Hewlett-Packard 400D

Reference 7

FIGURE 6.—DATA ACQUISITION SYSTEM
Scale-Model Test Facility (Annex D)

2.1.1.3 Test Procedure

Each day, prior to testing, an end-to-end calibration was made on each microphone system. In addition, background noise was recorded. The background noise data were reduced in octave bands in the same manner as the actual test data. If the signal-plus-noise-to-noise ratio was less than 10 dB, a correction was made; if it was less then 3 dB, the data were discarded. If more than one reel of tape was used on a given day the above procedure was repeated at the beginning of each reel.

A suppressor nozzle was mounted on the model-scale test rig and set to the specified temperature/pressure condition, allowed to stabilize, and acoustic data were taken for a period of 20 sec. If more than one temperature was called for, the lower temperature was recorded first. If a number of pressures were specified, the lowest pressure was recorded first. Performance data were recorded during the same time interval that acoustic data were recorded. A round convergent nozzle with the same exit plane area as the suppressor was then tested under the same engine conditions to provide a baseline for comparison.

2.1.1.4 Acoustic Data Reduction

A block diagram of the acoustic data reduction system is shown in figure 7 (from ref. 7). The data were reduced in eight preferred octave bands with center frequencies of 0.5, 1.0, 2.0, 4.0, 8.0, 16.0, 32.0, and 64.0 kHz.

The end-to-end acoustical calibration was performed at the beginning of each reel of tape. The calibrator used was a pistonphone that generates a 124-dB sound pressure level (SPL) re: 0.0002 dynes/cm^2 at 250 Hz. In data reduction, octave-band corrections were determined for the calibration of the microphones and the frequency response of the electronic systems. Total system correction was the sum of the two corrections for each octave band. All corrections were made relative to 250 Hz. The sample length for data reduction was 10 sec. The output of this system is the mean-rectified average of the 10-sec sample for each octave band in octave-band sound pressure levels (OB-SPL) expressed in dB re: 0.0002 dynes/cm^2.

The acoustic instrumentation system has an accuracy of ± 1 dB for the first seven octaves and $\pm$ 2 dB for the eighth octave band.

2.1.2 Hot-Nozzle Test Facility

The hot-nozzle test facility (HNTF) is located in Building 3.326 in the Mechanical Laboratory test area, adjacent to the north end of Boeing Field, Seattle, Washington. The HNTF was designed to test eighth-scale GE4 engine suppressor nozzle hardware with a flow area of 28.6 sq in. The purpose of the facility was to provide accurate exhaust nozzle performance data simultaneously with the acquisition of free-field radiated acoustic noise data.

The HNTF incorporates a primary air supply and burner system capable of providing hot gas up to 3000° F at a nozzle pressure ratio of 4.0. A strain gage load cell provides reactive thrust measurement to 2000 lb with repeatability of 0.5% full scale. The original burner system at the HNTF included five burners in parallel that discharged into a water-cooled mixing plenum and then into the duct section to which the model-scale nozzle was

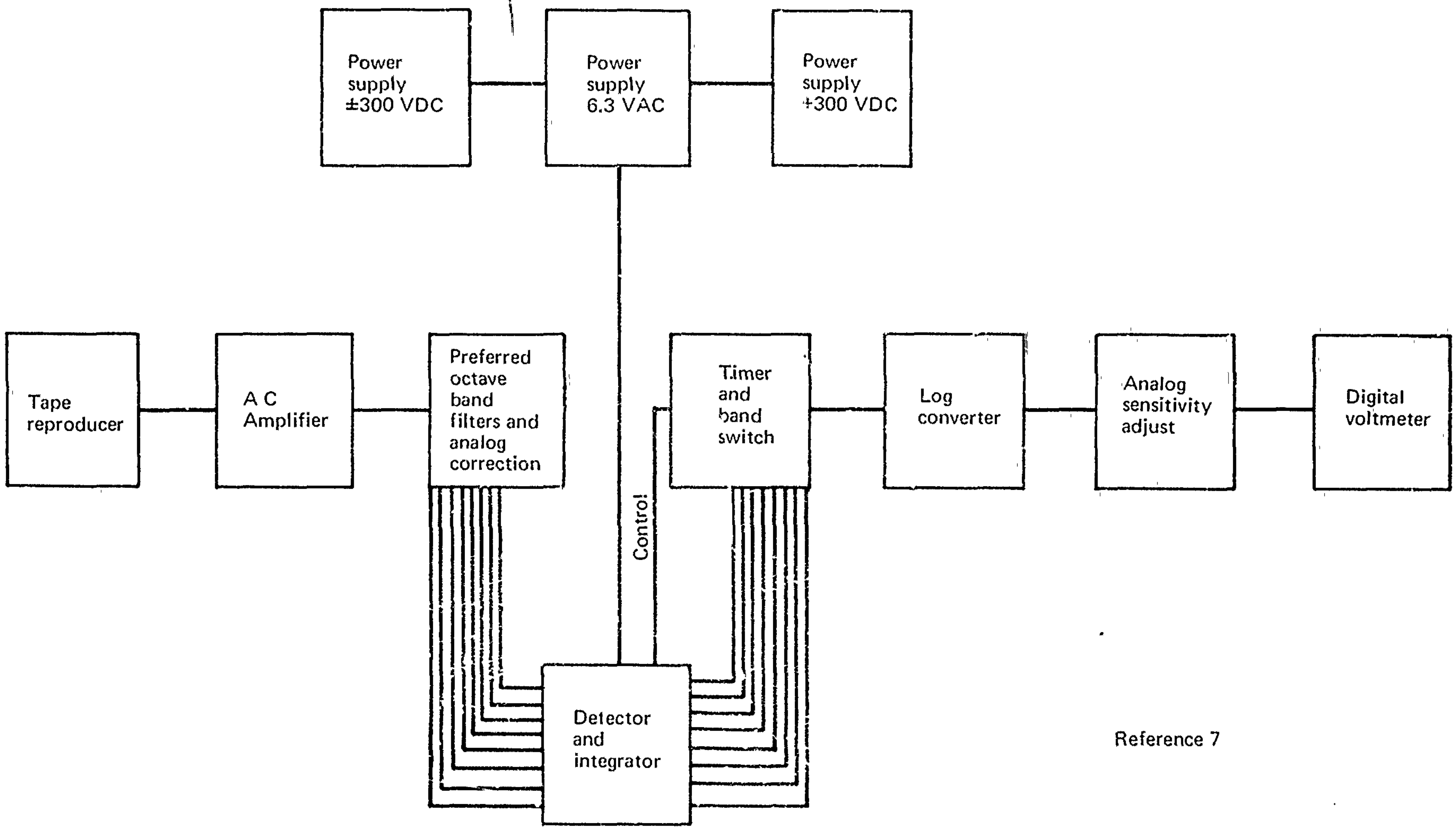


FIGURE 7.—ACOUSTIC DATA REDUCTION SYSTEM
Scale Model Test Facility (Annex D)—Octave Band

mounted. The original system (fig. 8) provided the desired flat temperature profile at the nozzle exit, however the system presented problems in operation, i.e., difficulties in igniting the burners and frequent overhaul of the system because of plenum erosion resulting from 3000°F operation. A subsequent burner system was installed that combined one primary burner followed by an afterburner that discharged directly into the water-cooled duct.

The afterburner produces large temperature gradients (i.e., 300° gradient across the primary exit flow field at an average total temperature of 1500°F). Random temperature variations with time (at a fixed point) are ±30 at 1500°F. To acquire average primary total temperatures, an area-weighted rake containing seven shielded chromel/alumel thermocouples is installed in the primary flow 4 in. upstream of the nozzle mounting flange. A seven-probe, area-weighted, total-pressure rake is located 180° from the temperature rake. Primary air weight flows and fuel flows are measured at ambient temperature for all run conditions. Area-weighted static-pressure pickups were installed on the nozzle baseplate when applicable.

Compressed air is supplied from a 300-psig source through a 160-psig regulator to the facility. A remotely operated control valve is used to regulate the air supply. The primary and secondary flow metering systems are designed to ASME standards and are located downstream of the regulator valves. These systems contain high-beta-series ASME flow nozzles. The primary air is ducted from the flow metering system to a cold-air plenum through two diametrically opposed thin-wall pipes. This plenum supplies air to the burner where JP-series fuel is introduced and ignited. The burner discharges into a water-cooled duct section to which the exhaust nozzle model is mounted. Nozzle reactive thrust is transmitted directly through the flexure-supported thrust rig to a strain gage load cell.

A 180° acoustically clear area is provided for a maximum 50-ft radius outboard of the nozzle exit station. This area is graded flat and covered with river rock. An arena fence and an acoustic baffle were constructed and installed, (figs. 9 and 10).

2.1.2.1 Internal Flow and Performance Instrumentation

Airflow was measured using a 3.5-in.-diameter ASME flow nozzle. Fuel flow was measured with a 5/8-in. Potter flowmeter. Nozzle reactive thrust was sensed with a 2000-lb Baldwin Lima Hamilton loadcell. Maximum available airflow is 35 lb/sec. Nozzle total pressure was measured with a single water-cooled probe approximately 63 in upstream of the nozzle exit.

Model and airflow measuring pressures were sensed with Consolidated Electrodynamics and Statham pressure transducers that were accurate and repeatable to ±0.25% full scale.

The force, temperature, and pressure ' . were automatically scanned and recorded using the HNTF Dymec data system. The individual transducer outputs were conditioned and amplified using a Hewlett-Packard crossbar scanner (DY-2911A) and data amplifier

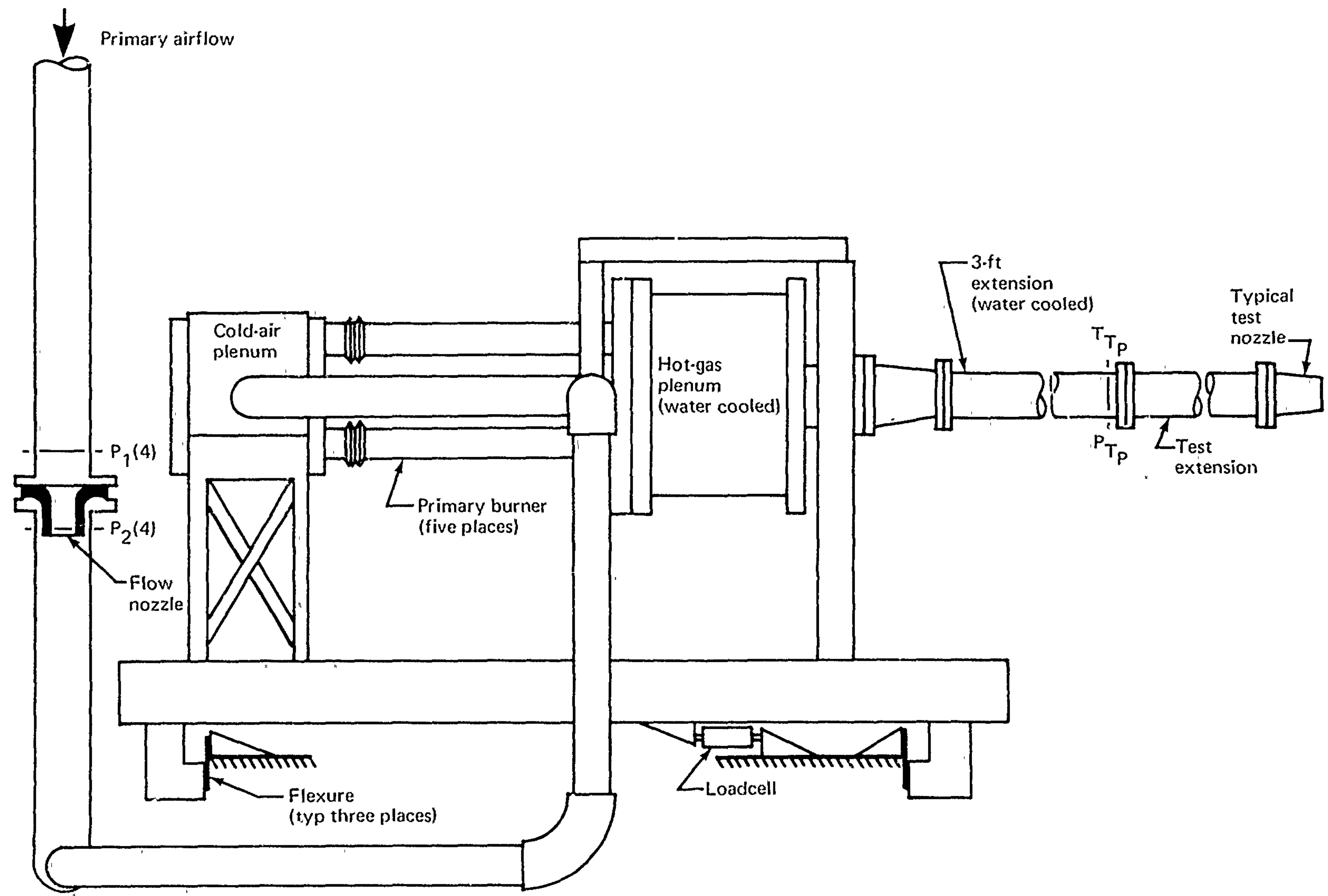


FIGURE 8.—HOT-NOZZLE TEST FACILITY

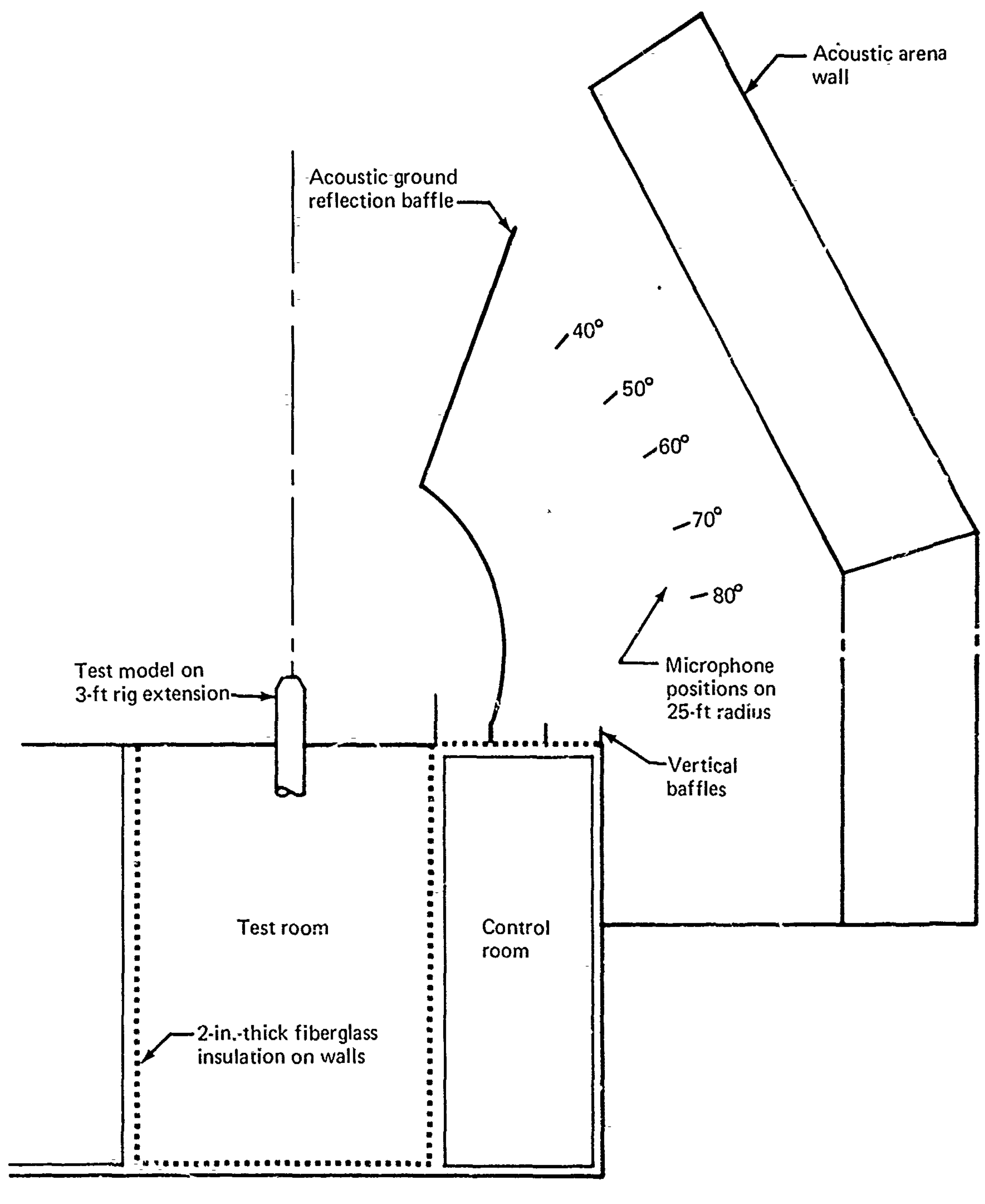


FIGURE 9.—HOT-NOZZLE TEST FACILITY, ACOUSTIC ARENA LAYOUT

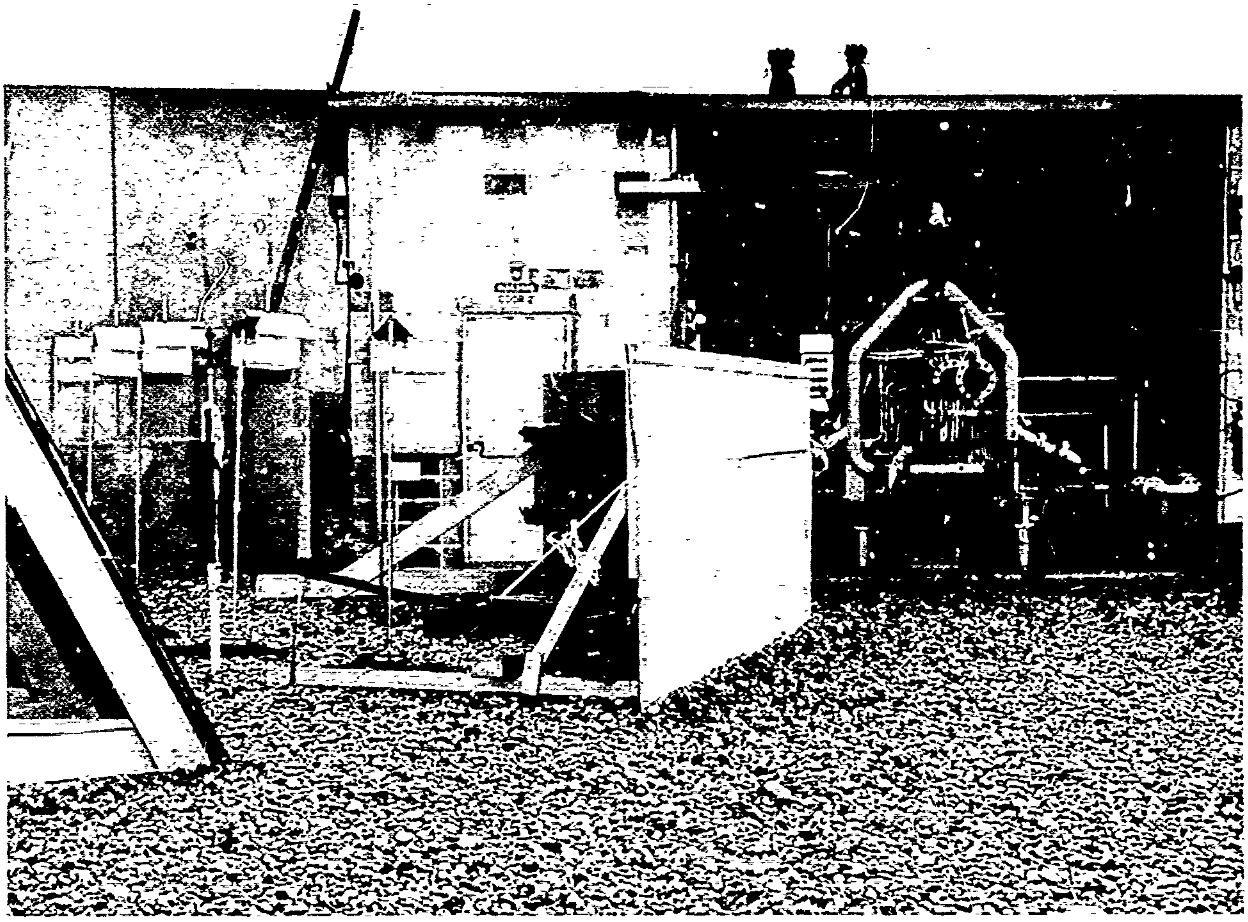


FIGURE 10.—HOT-NOZZLE TEST FACILITY, ACOUSTIC ARENA PHOTOGRAPH

These signals were fed through a digitizing voltmeter (DY-2401C) and stored in digital form on punched paper tape. The data were then transferred to IBM cards using an IBM 047 tape-to-card converter.

2.1.2.2 Acoustic Instrumentation

A 14-channel tape recorder and associated electronics were used to record acoustic noise levels. The tape system had a usable frequency range from 150 to 80,000 Hz and included a voice channel and time sequence input. A level recorder was used to provide a direct readout of third-octave-band data. The entire acoustic data system was field calibrated (see fig. 11).

Five to twelve 0.25-in.-diameter condenser-type microphones, located on a radius 25 ft from the nozzle exit plane and at selected angles to the nozzle centerline, were used to measure the noise levels due to the jet efflux. These microphones were mounted at nozzle centerline height and pointed toward the nozzle exit plane.

2.1.2.3 Test Procedure

The nozzle operating conditions (pressure and temperature) were monitored on digital voltmeters and manually controlled by varying air and fuel flow. After setting the desired exhaust temperature, a series of data points was taken at various nozzle pressure ratios. After stabilization of all parameters (approximately 15 sec), thrust, weight flow, and temperature values were recorded. All pressures were trapped (using cutoff values), scanned, and recorded sequentially. During this same period, acoustic data were being recorded on magnetic tape from the microphones in the acoustic arena.

A round-convergent reference nozzle with a 6-in. exit diameter was run periodically at the same suppressor nozzle operating conditions to ensure proper operation and repeatability of all systems and to provide a noise baseline for acoustic data.

2.1.2.4 Performance Data Reduction

The recorded digital performance data were combined with the IBM 290.08 data reduction program and processed on the CDC 6600 computer.

The reduced performance data included the following parameters:

- Measured primary air flow rate W_A
- Measured primary fuel flow rate W_f
- Primary gas flow rate $W_{act} = W_A + W_f$
- Nozzle pressure ratio P_T/P_∞
- Nozzle gas average total temperature T_T
- Nozzle ideal fully expanded jet velocity V_I

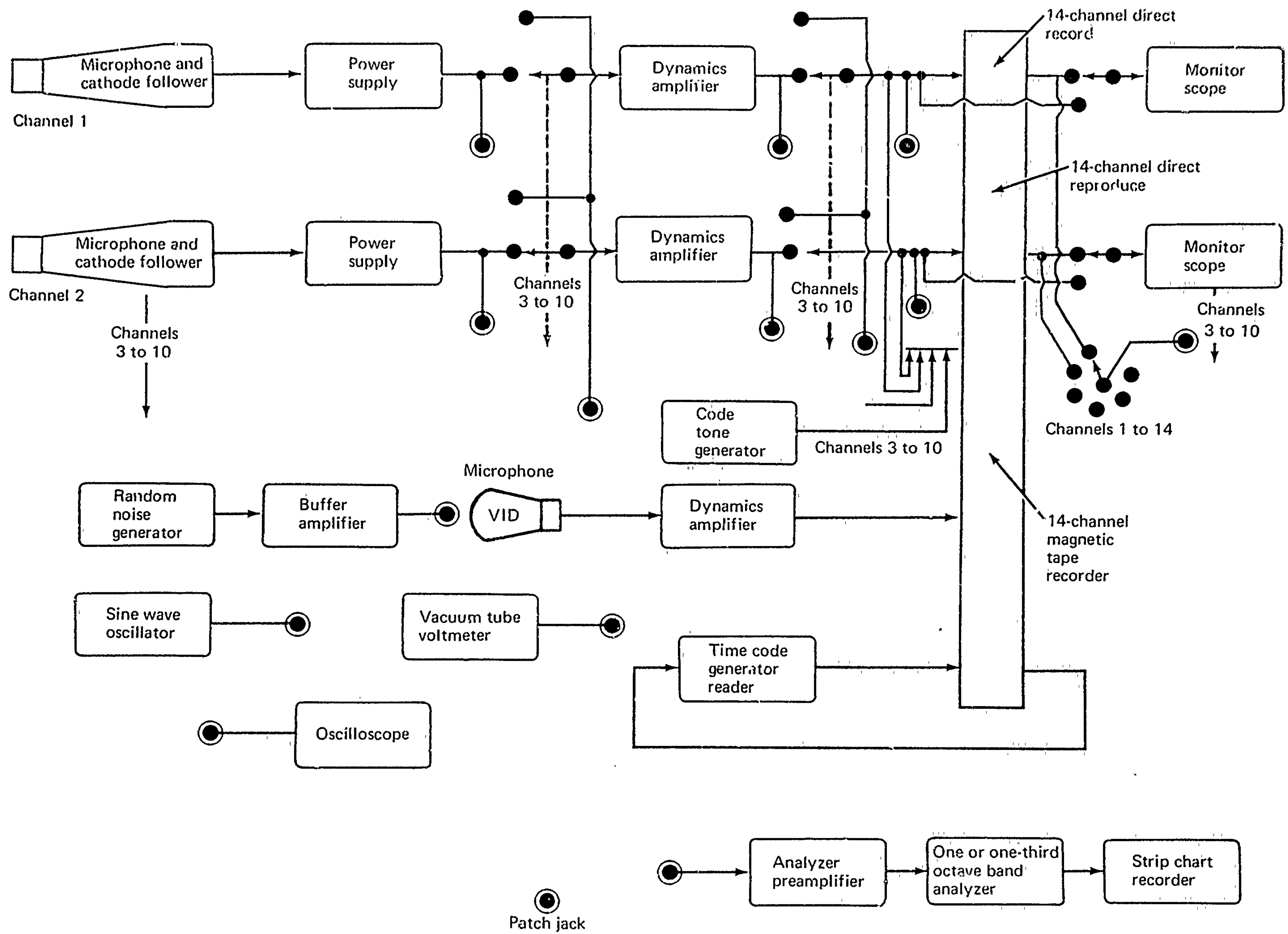


FIGURE 11.—HOT-NOZZLE TEST FACILITY, ACOUSTIC DATA RECORDING SYSTEM, 1970

- Calculated isentropic flow area A_E^*
- Nozzle thrust F
- Ideal thrust F_I
- Nozzle cross thrust coefficient $C_{Fg} = \dfrac{F_{measured}}{(W_{act}\ V_I/g)_{primary}}$
- Nozzle velocity coefficient $C_V = \dfrac{F_{measured}}{(W_{act}\ V_I/g)_{primary} + (W_{act}\ V_I/g)_{secondary}}$
- Nozzle discharge coefficient $C_D = \dfrac{\text{measured primary weight flow}}{\text{ideal primary weight flow}}$
- Baseplate and ejector wall pressure ratios $P_B/P_\infty\,;\,P_S P_\infty$
- Average base pressure ratio P_{Bavg}/P_∞
- Baseplate drag ratio D_B/F_I

2.1.2.5 Acoustic Data Reduction

Acoustic data were reduced off magnetic tape on the same system described in section 2.1.1.4. During 1970, another data reduction system was employed at the CAG acoustic laboratory that provided true rms, third-octave band levels on 80-column IBM cards. The acoustic data reduced on IBM cards was used with existing CDC 6600 computer programs to provide extrapolated sideline perceived noise levels and with SC 4020 plotting routines to provide noise spectrum plots.

2.2 FULL-SCALE

2.2.1 B1 Test Pad at Boardman, Oregon

The bulk of full-scale suppressor nozzle testing prior to mid-1968 was accomplished at test pad B1, Boardman, Oregon. A portable thrust stand with a J-75 engine for a hot-gas generator was installed. The J-75 engine was oriented with the exhaust nozzle pointing northeast. A permanent blockhouse containing the engine performance instrumentation and acoustic recording equipment was located 650 ft southwest of the engine. The acoustic field was to the north of the engine (fig. 12, from ref. 10). The acoustic field had a natural ground floor composed primarily of sand and sparse vegetation.

2.2.1.1 Internal Flow and Performance Instrumentation

The performance characteristics checked are as follows:

- Temperatures (3 sensors)
    - Fuel inlet (1)
    - Turbine Discharge (1)
    - Outside air (1)

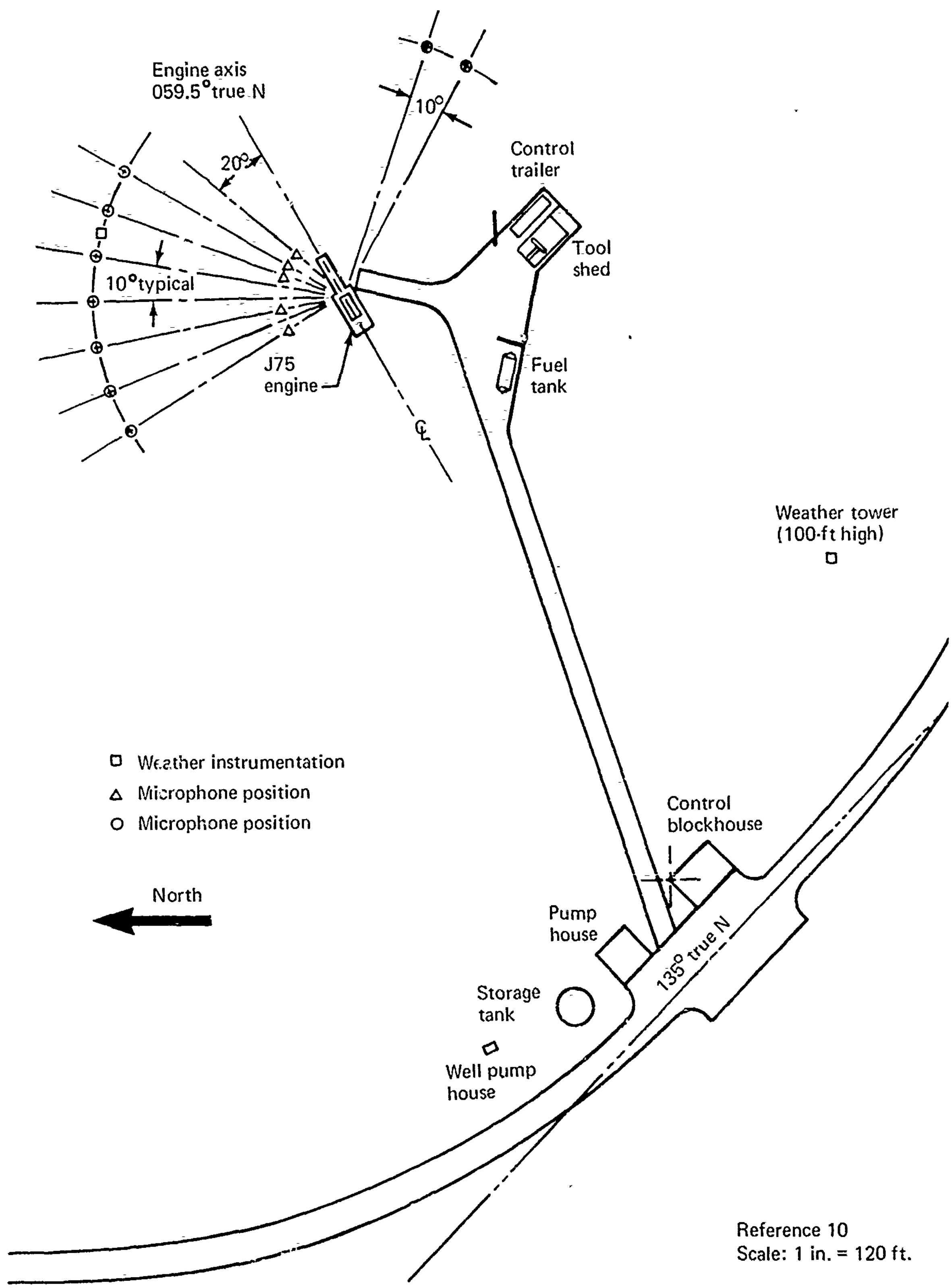


FIGURE 12.—B1 TEST PAD AT BOARDMAN, OREGON

- Pressures (59 sensors)
  - Turbine discharge (1)
  - High-pressure compressor discharge (1)
  - Ejector wall statics (24)
  - Ejector chute statics (14)
  - Ejector inlet statics (3)
  - Ejector inlet totals (3)
  - Engine inlet statics (12)
  - Ambient (1)
- Engine component speeds (2 sensors)
- Weight flows (1 sensor)
- Thrust measurement (1 sensor)
- X-Y plots (1 sensor)
- Vibration (3 sensors)

A simplified block diagram of signal paths only is shown in figure 13 (from ref. 10).

An environmentally controlled instrumentation trailer was located approximately 40 ft south of the engine test stand. The equipment located in the trailer included chromel-alumel 150° F reference junctions, pressure transducers, scanivalves and associated driver, chop valves, and power supply for the driver.

All engine controls and indicating devices for control of the engine were located in the control trailer approximately 120 ft south of the engine stand. Of the instrumentation requirements, only the three vibrations were read out manually in the control trailer.

The recording instrumentation system and the remainder of the signal conditioning equipment were located approximately 600 ft southwest of the engine stand in the blockhouse.

All temperature readouts were derived from chromel-alumel thermocouples and appeared as millivolt outputs in digital display. Engineering units were derived either manually or from a computer using standard 150° reference millivolt-to-temperature conversion charts. These charts also provided the means for system checks. By imposing a given millivolt level at the output of the reference junction, it was possible to read directly the impressed voltage at the system output. The millivolt source used was a Leeds and Northrup millivolt potentiometer, model 8686.

With the exclusion of the ambient pressure, all pressures were trapped simultaneously in volume chambers by automatically operated chop valves. These pressures were then sampled either through the use of scanivalves and scanivalve transducers or by individual transducers in the case of P_{T7} and P_{S4}. All of the transducers were calibrated from a

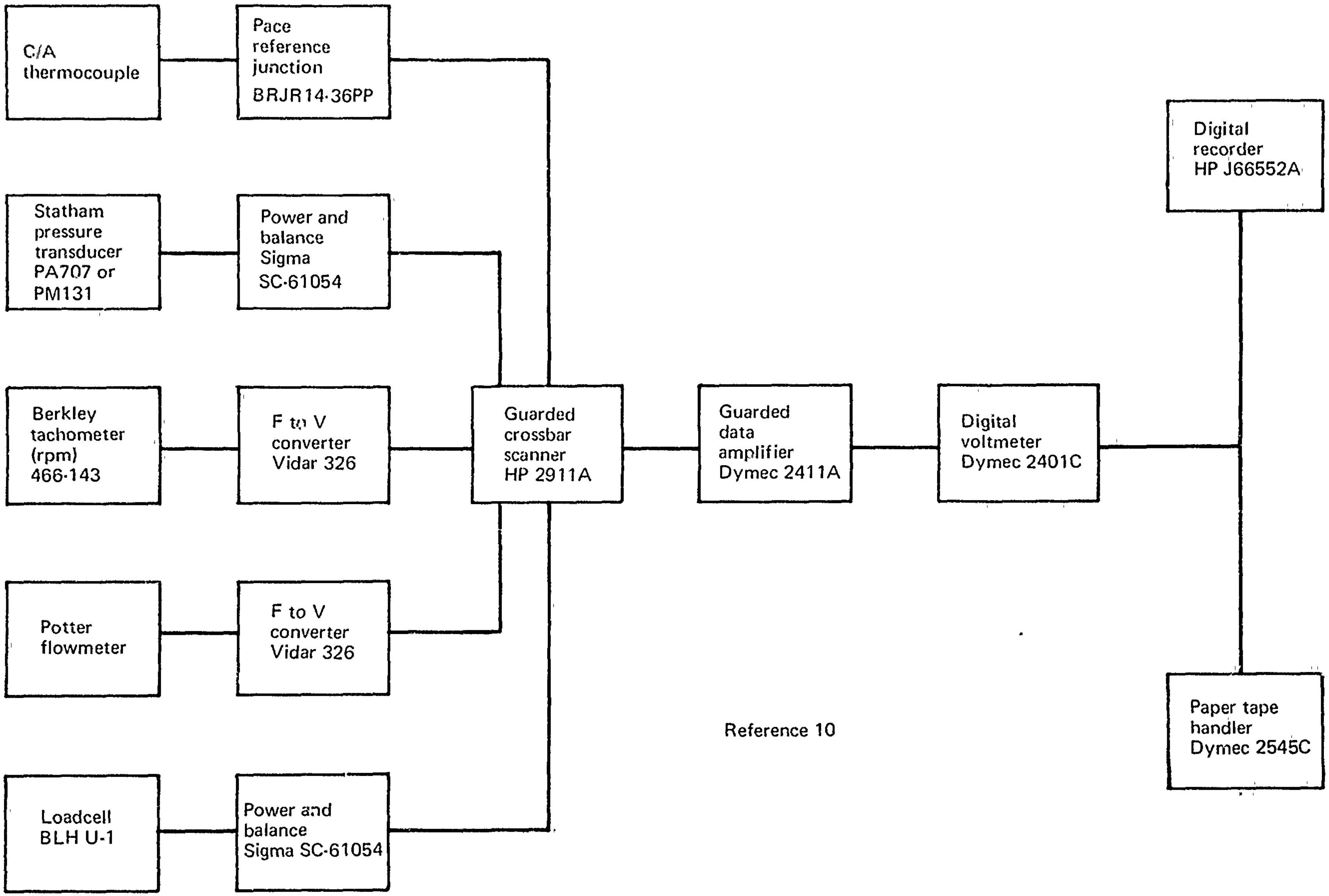


FIGURE 13.—BLOCK DIAGRAM OF TYPICAL SIGNAL PATHS

calibration panel in the control trailer with the use of a controlled external pressure from a dry nitrogen bottle. Pressures so applied were monitored by Wallace and Tiernan pressure gages, calibrated in inches of mercury, to an accuracy of ±0.1%.

All system calibration frequencies for tachometer and flow meter outputs were calculated using the following equation:

$$f = \text{gear ratio} \times \text{teeth} \times \text{rpm} \times \text{min}/60 \text{ sec} = \text{cps}$$

- N_1—Low-Pressure Rotor Speed
  Gear ratio = 0.62
  Tachometer teeth = 143
  RPM = 10,000

  Therefore,

  $$f = 0.62 \times 143 \times 10{,}000/60 = 14{,}777 \text{ cps}$$

  Applying this frequency to the Vidar frequency-to-voltage converter enabled the voltage output of the Vidar to be divided through a potentiometer to yield a reading of 10,000 counts on the data system equal to 10,000 rpm.

- N_2—High-Pressure Rotor Speed
  Gear ratio = 0.481
  Tachometer teeth = 143
  RPM = 10,000

  Therefore,

  $$f = 0.481 \times 143 \times 10{,}000/60 = 11{,}464 \text{ cps}$$

  The same calibration procedure used for N_1 was also used for N_2.

- W_F—Fuel Weight Flow
  The same calibration procedure was used for W_F as for N_1 and N_2 with the frequency extracted from the laboratory calibration sheet for gallons per minute. 554 cps yielded 102.50 gpm.

Engine thrust measurements were calibrated with the aid of a Baldwin-Lima-Hamilton standard load cell ad indicator with digital readout in pounds. The calibration cell was placed between the stand and a fixed "dead man" and a load was pulled hydraulically. By recording the outputs of both the engine load cell and the standard cell, a correction curve was resolved for the combination of engine stand and load cell. These "thrust pulls" were generally carried out prior to each series of runs or whenever deemed necessary by test or instrumentation engineers.

The accuracy of the measurements were as follows:

F	±60 lb
P_{T7}	±0.2 in. of Hg
P_{AMB}	±0.08 in. of Hg
T_{T7}	±10°F
OAT	±4° F
T_{FI}	±4° F
N_1	±20 rpm
N_2	±25 rpm
P_{T2}	±0.01 in. of Hg
W_F	±0.03 lb/sec
P_{S4}	±1.6 in. of Hg

Tertiary air static and total pressure (P_{IS}, P_{IT}) were used to find the tertiary airflow. There were two sets of probes. One set had three static-pressure probes while the other had three total-pressure probes. The total-pressure probes were manifolded together to give one reading. When the blow-in-door (BID) simulator was used, the probes were in the doors of the simulator. When the BID was not used, the set of total-pressure probes was at the 10 o'clock position and the set of static-pressure probes at the 2 o'clock position. (The position is determined by standing at the rear of the engine and looking forward.)

2.2.1.2 Acoustic Instrumentation

Microphones were placed along a circular arc of 200-ft radius from the engine nozzle at 10° intervals from 30° to 80° and set up at grazing incidence to the centerline height of the engine nozzle. The microphones measured the sound pressure levels (SPL) created by the J-75 engine (with an afterburner) for various hardware configurations and power settings. Microphone outputs were recorded on magnetic tape for later data reduction.

Altec model 21BR-180-1 microphones were used for the entire test. These capacitor-type microphones were attached directly to cathode follower preamplifiers (Altec model 165A). Six cables 200 ft long carried the signals from the six cathode followers to six microphone power supplies (Altec model 526B). Cable 500 ft long carried the signals from the output terminals of the power supplies to the recording system located in the blockhouse. Due to the long distances between the microphones and the recording system, impedance matching systems were set up between the microphone power supplies and the preamplifiers of the tape recorder. The impedance matching systems consisted of stepdown transformers

(50,000 to 50 ohms) from the power supply's output through 500 ft of instrumentation cables into step-up transformers (50 to 50,000 ohms), mounted on the instrumentation rack in the blockhouse. A block diagram of the instrumentation system is attached (fig. 14, from ref. 10).

The microphones were calibrated by the comparison method in an acoustic pressure coupler. A Western Electric model 640AA microphone with calibration traceable to the National Bureau of Standards was used as a standard. This pressure coupler was designed to operate from 40 to 8000 Hz.

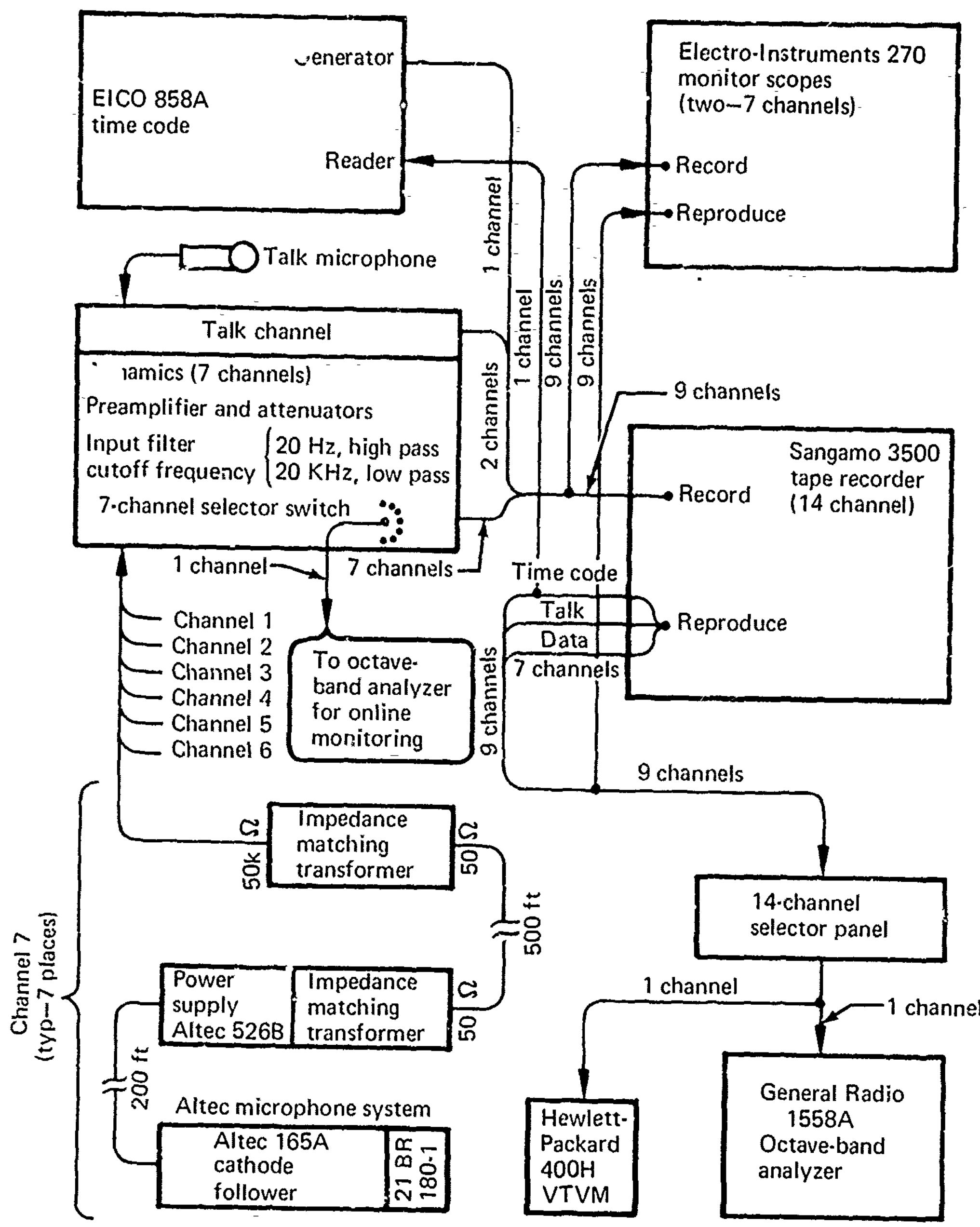
An end-to-end calibration was performed on each microphone before each test. The calibrator used was a Bruel and Kjaer pistonphone model 4220, which generates a 124-dB SPL re: 0.0002 dynes/cm^2 at 250 Hz. The SPLs, as indicated on a VTVM, were then related to the preamp code tone, 400 Hz at 1.0 volt rms = +2.2 dB at 0 dB gain. The reference SPLs at 400 Hz, therefore, came out differently for each microphone, depending on the gain setting of the preamplifier and the level read on the VTVM when the pistonphone was applied to the microphone. This technique made possible the direct calibration of all channels in one step by recording the code tone at 1 volt rms on magnetic tape for 30 sec.

Once a week, a frequency response check of the microphone system was performed. A Bruel and Kjaer random noise source, type 4240, which generates 108 dB overall SPL for 15 sec, was applied to each microphone, and the signals were recorded on magnetic tape set aside for this purpose. The data acquired were later analyzed and the results checked against the previous week's results for repeatability. Comparisons showed maximum deviations of $\pm$1.0 dB, which is well within the specified tolerance.

The output voltages of the fixed-position microphones were amplified by preamplifiers and the amplified signals recorded on a 14-channel Sangamo 3500 tape recorder. The tape recorder was operated at 30 ips in the FM and direct-record modes. Channels 1 through 6 recorded data in FM mode, while channels 13 and 14 recorded voice and time code, respectively, in the direct mode. This was considered the most favorable mode for the test since the tape recorder had a flat frequency response from 50 Hz to 10 kHz, as indicated when a frequency sweep 20 Hz to 10 kHz was run through every channel and the response plotted by a Bruel and Kjaer model 3304 automatic frequency response recorder. The tape recorder frequency response was down 0.5 dB from 20 to 50 Hz, which was compensated for during data reduction.

Once a week, the limiting frequencies (64.8 and 151.2 kHz) and the center frequency (108 kHz) of the FM record cards were checked (and adjusted when necessary) by inserting $\pm$1.4 Vdc and 0 Vdc signals, respectively, into the input of each channel and feeding the output into a Dymec frequency counter. (The dc voltage supply was checked and adjusted for the above values on a Dana digital voltmeter.)

The data reduction system consisted of the Sangamo tape recorder, a Hewlett-Packard VTVM, and a General Radio octave-band analyzer, model 1558A. Before data analysis, the playback cards were checked and adjusted when necessary to give 1 volt rms (measured by the VTVM) response to the calibration signal as reproduced by the tape recorder.



Reference 1(

FIGURE 14.—BLOCK DIAGRAM OF ACOUSTIC DATA ACQUISITION AND REDUCTION INSTRUMENTATION AT BOARDMAN

The calibration signal (400 Hz) of a specific magnitude SPL, as identified on voice channel and noted on log sheet for a particular channel, was played back directly into the octave-band analyzer with the octave-band filter set at 300 to 600 Hz. The calibration potentiometer was adjusted for the given SPL, thus calibrating the octave-band analyzer for the data recorded thereafter.

Data samples were then played back into the calibrated octave-band analyzer and, by manually switching the octave-band filter, the SPLs for the standard octave bands were read off the meter directly. The octave-band corrections for the whole system, as determined by the sum of the deviations from the ideal flat frequency response for the microphones, the tape recorder, the electronic system, and the cables , were then added to the data obtained and the corrected data tabulated as octave-band SPL versus test point and run number. All test data were analyzed in this fashion for all microphones.

The maximum day-to-day microphone calibration repeatability using the Bruel and Kjaer pistonphone for all microphones used for the test was ±0.5 dB. The frequency response checks, using the Bruel and Kjaer noise source, type 4240, on all microphones showed a maximum deviation of ±1.0 dB in some octave bands. Manufacturer's specification on noise source is ±1.0 dB repeatability. Data reduction was slow, tedious, and possibly inaccurate for data recorded in windy weather (8 mph and over). High winds created disturbances in the sound propagation path and caused meter fluctuations ranging from 3 to 10 dB on the octave-band analyzer level indicator. In such cases, the average value was taken.

2.2.1.3 Meteorological Instrumentation

Meteorological data obtained for these test series were air temperature at five levels, humidity at one level, and wind speed and direction at two levels, all from one tower. A tripod-mounted wind unit was mounted at another location for a remote measurement of wind speed and direction. All data were recorded in chart form as ink traces of a data analog.

Beckman and Whitley 15-64 and 15-65 wind speed and direction sensors are the industry standard and are common at research stations of all governmental agencies and armed services. This point is important, because it allows close comparisons to be made among many data sources.

Wind speed was sensed by a lighweight three-cup anemometer which begins turning at speeds of about 0.5 mph. The cups are used to rotate a plotted disc acting as a light chopper between a light source and a phototransistor producing pulses that are converted to an analog current.

Horizontal wind direction was sensed by a vane, connected to a precision potentiometer that was one arm of a voltage divider network. The resultant output was converted to a current analog linear with direction. Vertical components were not available.

On the west face of the tower near the blockhouse, there was one of each sensor at 3 and 33 meters above the ground surface. A similar vane was mounted on a tripod near the 30 microphone with the sensor height at 3 meters.

Data were recorded on Esterline Angers strip-chart recorders, model AW, located in the blockhouse. Chart speeds were normally 3-in./hr, except during test periods when 3-in./min were used for better resolution. Accuracy for the low-wind conditions of the test was better than 1 mph of speed and 2° to 3° in azimuth.

All of the humidity values were from measurements made with a wet bulb-depression thermocouple psychrometer. The resultant wet- and dry-bulb values were converted to relative humidity, accurate to within 5%.

Thermocouples of copper-constantan were used entirely for temperature measurements. These were referenced against a 1-meter-deep ground thermocouple that was, in turn, calibrated against an ice bath once or twice each week. Variations in the ground reference temperature of less than 1° F were usual, which is comparable to the variation in methods of measuring air temperature under these conditions. The thermocouple emf was fed into a Leeds and Northrup model-G potentiometer-type recorder that amplifies and records as a 0.5-sec mean value once or twice each minute.

Electrically powered aspirators with a high degree of solar and infrared radiation shielding house the air-sensing thermocouples. These were also of Beckman and Whitley manufacture and were mounted to sense air from a layer less than 10 cm deep at heights of 0.25, 2, and 32 meters. Thermocouples were also mounted at 1 meter in the sand and on or near the sand surface. The former was sealed and insulated to damp out transients of less than 1 day duration, and the latter was part of a 1-in.-square plate of copper usually covered with a half millimeter or so of fine sand.

2.2.1.4 Test Procedure

The following procedure was followed when testing a suppressor nozzle configuration:

- Bring engine up to desired engine pressure ratio.
- Allow engine to stabilize for 3 min to ensure correct performance data.
- During this 3-min period, monitor the acoustic field with an on-line octave-band analyzer.
- At the 3-min point, record performance data, weather data, and acoustic data for 30 sec.
- At the 4-min point, obtain recorded performance data again.
- Shut down.

2.2.2 B2 Test Pad at Boardman, Oregon

The B2 test pad at Boardman, Oregon was established to facilitate the acquisition of free-field acoustic data of supersonic jet radiated noise. This test pad was operational in

mid-1968. A YJ-93 turbojet engine installation was used as the hot-gas generator. This engine was able to attain a higher nozzle pressure ratio at afterburning temperatures than the J-75 engine used in earlier tests.

The engine was mounted on a thrust stand with the engine centerline 7.3 ft above the local ground plane. The bellmouth inlet faced in a west-south-westerly direction (239° true).

The northeast quadrant was paved with concrete out to a radius of 250 ft from the center of the exhaust nozzle. This concrete pad was machine finished to within 0.25 in. of flat. The area immediately surrounding and under the engine was covered with steel plate. A strip of large rocks extended beyond the steel plates under the jet wake to reduce erosion. These rocks protruded randomly about 1 ft above the level of the concrete.

The engine was controlled from a blockhouse located about 500 ft south of the engine. All engine and nozzle performance data were monitored and recorded in the blockhouse. All acoustic data were recorded in the acoustic trailer.

A maximum (nonafterburning) nominal nozzle pressure ratio of 2.8 and temperature of 1600° F was available when the nozzle area was properly matched to the engine.

2.2.2.1 Internal Flow and Performance Instrumentation

Appropriate instrumentation was used to supply performance-related data, such as:

P_{amb}	Barometric pressure
T_{amb}	Atmospheric temperature
P_{T2}	Total pressure at compressor inlet
P_{S2}	Static pressure at compressor inlet
RPM	Rotor speed
W_{fuel}	Fuel flow rate
F_N	Measured engine thrust
P_{T5}	Total pressure at turbine exit
T_{T5}	Total temperature at turbine exit
P_{T7}	Total pressure at nozzle entrance
T_{T7}	Total temperature at nozzle entrance
P_{SB}	Suppressor nozzle static base pressure

Instrumentation was similar to that used on the B-1 test pad, section 2.2.1.2.

2.2.2.2 Acoustic Instrumentation

Noise data were acquired through six Altec 21 BR microphones. These were placed 200 ft from the center of the exhaust nozzle at angles of 30°, 40°, 50°, 60°, 70°, and 80° from the jet exhaust axis at a height of 7.5 ft above the concrete pad and oriented with the diaphram of the microphone facing upward. Another set of six microphones was set at the same angles about 1 in. above the concrete ground floor. This provided measurements that were 6 dB above the free-field levels due to pressure doubling at the concrete/air interface. The reduced acoustic data were adjusted by –6 dB to arrive at free-field spectrum levels.

Signals from the microphones passed through a transformer to match impedance with an 800-ft transmission line leading to an Ampex ES 100FM magnetic tape recorder. The transformers and power supplies were buried in a double-walled box to avoid microphonics and extraneous reflections. Thirty-second data samples from the magnetic tapes were recorded on magnetic tape loops and replayed into an automatic third-octave-band analyzer. The third-octave-band levels were recorded on punch tape. These punch tapes, along with data acquisition parameters, were fed into a card puncher. The corrected third-octave- and full-octave-band levels were calculated by computer (IBM 360) and punched onto cards for further processing.

The sensitivity of the system was determined by a pistonphone calibration at 124 ±2 dB and 250 Hz made before or after each run. The frequency response was determined by an insert calibration made within 48 hr of each test. This consisted of a sweep of 1 + 0.01 V pure tone signals at frequencies ranging from 20 to 20,000 Hz. The signals were applied at the cathode follower input with button loading included.

The total data scatter (based on OASPL) including variations in the noise source, atmosphere, and the data acquisition and reduction systems was observed to be less than 2 dB maximum to minimum. The data acquisition and reduction systems have an accuracy of ±3 dB and a 1.6-sigma deviation of ±1 dB (i.e., 90% of all data points will deviate from the mean by less than 1 dB). The above apply only in cases where noise floor interference is absent or insignificant.

2.2.2.3 Meteorological Instrumentation

The data from three instruments were used for the acoustic and performance analyses. The instruments (an anemometer, a psychrometer, and a thermocouple) were mounted on a tower located 700 ft from the engine test stand. The anemometer was mounted 10 ft above the ground and the remaining instruments 6 ft above the ground. Additional instruments were placed at other levels on the tower and on stands at other locations on the test site, but the data from these were used only as a check. The accuracy of the anemometer data is within 2 mph and 10° of arc, the thermocouple is within 2°F, and the psychrometer is within 5% relative humidity. Meteorological instrumentation was similar to that described in section 2.2.1.3.

2.2.2.4 Test Procedure

Prior to each run, all acoustic and performance instrumentation was set up and calibrated, and the engine and suppressor received a thorough visual inspection. The engine was then started and idled for 5 min while another check of instrumentation and engine hardware was conducted. After completing the above engine checkout procedure, the engine was brought to the first test condition and allowed 2 min to stabilize. After stabilizing, two scans or separate sets of acoustic and performance data were recorded. The total engine time required to set a condition, stabilize, and record data was about 5 min. After running all of the conditions listed below, the engine was idled for 5 min and shut down.

Turbine exit total pressure P_{T5} was used as a guide in setting all engine conditions except the highest condition where the engine limits were used. The P_{T5} levels used were computed from the desired nozzle pressure ratio, ambient pressure, and afterburner pressure drop.

Test runs were made if weather conditions were within the following limits:

Temperature	32° to 80° F
Relative humidity	Greater than 30%
Wind speed	Less than 8 mph
Precipitation	None
Fog	None

2.3 EXTRAPOLATION OF ACOUSTIC DATA

The Boeing SST Aircraft Noise unit used an integrated noise extrapolation procedure based on the following Society of Automotive Engineers (SAE) publications, references 14, 15, and 16.

The procedure has been computerized and is described in detail in reference 17. Effects considered in sound propagation between the source (jet engines) and observer follow:

Spherical divergence	AIR 876 (ref. 14)
Number of engines and engine shielding	AIR 876 (ref. 14)
Atmospheric absorption	ARP 866 (ref. 15)
Extra ground attenuation	AIR 923 (ref. 16)

The sum of all these effects was used to extrapolate ground-static acoustic data to flight conditions for noise-suppressor evaluation.

Boeing was conducting eighth-scale model suppressor nozzle tests in the design/development of a noise suppressor that could be used on the SST. The eighth-scale acoustic test data were scaled up to full-scale conditions by use of the Strouhal number relationship described in AIR 876 and then extrapolated to flight conditions.

The Strouhal number scaling technique consists of dividing the model noise data frequencies (Hz) and multiplying *all* model linear dimensions by a scale factor determined from the following equation:

$$\text{Scale factor} = [A_1/A_2]^{1/2}$$

where (A_1, A_2) are the nozzle discharge areas, respectively, for full-scale and model-scale burners or engines operating with *identical* primary gas conditions of pressure ratio, total temperature, and gas composition.

The scale factor was also applied to the distance relationship between the sound source and the microphone station. For instance, in eighth-scale acoustic tests, a microphone distance of 25 ft is equivalent to 200 ft full scale. The air absorption loss in dB was assumed to be negligible for the test distance employed between microphone and jet. The assumption is naive when considering the extreme high-frequency end of the spectrum in model-scale data; however, there was little effect on perceived noise level calculations. More information is required concerning air propagation anomalies in the ultrasonic range before model-scale jet noise data can be successfully adjusted to a standard-day condition.

Measured acoustic data were extrapolated to the observer position by applying propagation loss factors (e.g., spherical divergence, atmospheric absorption, extra ground attenuation, etc.) given in ARP 866, AIR 876, and AIR 923.

The adjusted acoustic signatures were transformed into perceived noise levels (PNdB) using the procedures outlined in ARP 865 (SAE). The observer reference position considered prior to the establishment of FAR 36 was the 1500-ft sideline parallel to the jet axis. After 1969, the 2128-ft sideline (0.35 nmi) was used as the observer reference position and the propagation loss factors adjusted accordingly. Typical ground-to-ground sound propagation losses, including spreading loss, employed in extrapolating 200-ft polar arc acoustic data to the 1500-ft sideline are given in table 1 for preferred octave bands. These propagation losses are for standard-day conditions of 59.0° F and 70% RH. Table 2 lists sound propagation losses used in extrapolating from the 200-ft polar arc to 2128-ft sideline. It should be noted that the current SAE standards do not predict accurately the sound propagation losses for 1500- and 2128-ft sideline distances. Measurements taken at Boardman, Oregon at the 800- and 1500-ft sideline indicated that large standard deviations (approximately 10 dB) of sound pressure levels exist for all octave bands (ref. 18). It is suspected that ground reflection interference and ducting of radiated acoustic noise affects sound propagation loss significantly in ground-to-ground measurements. Air-to-ground sound propagation loss anomalies are probably less severe.

TABLE 1.—SOUND PROPAGATION LOSS IN DB (GROUND TO GROUND)
200-FT POLAR ARC TO 1500-FT SIDELINE

Angle to jet axis (deg)	Preferred octave bands							
	1 63 Hz	2 125 Hz	3 250 Hz	4 500 Hz	5 1 kHz	6 2 kHz	7 4 kHz	8 8 kHz
30	28.4	30.2	32.8	35.4	39.1	44.9	58.1	76.8
40	25.5	27.3	24.5	32.0	34.8	39.7	49.7	64.0
45	24.0	26.0	27.5	30.5	33.0	38.0	47.0	60.0
50	23.6	25.2	27.1	29.5	31.8	36.2	44.4	56.2
60	22.3	23.7	25.4	27.5	29.7	33.6	40.8	51.1
70	21.2	22.5	24.0	26.0	28.3	31.8	38.3	47.7
80	20.6	21.8	23.4	25.1	27.3	30.7	36.9	45.8
90	20.5	21.7	23.1	24.9	26.9	30.4	36.5	45.2

TABLE 2.—SOUND PROPAGATION LOSS IN DB (GROUND TO GROUND)
200-FT POLAR ARC TO 2128-FT SIDELINE

Angle to jet axis (deg)	Preferred octave bands							
	1 63 Hz	2 125 Hz	3 250 Hz	4 500 Hz	5 1 kHz	6 2 kHz	7 4 kHz	8 8 kHz
30	31.6	34.3	37.3	40.7	45.6	52.9	72.2	98.9
35	30.7	33.0	35.8	38.9	43.4	49.9	66.5	89.6
40	29.6	31.9	34.5	37.5	41.5	47.4	62.2	82.6
45	28.7	30.8	33.3	36.2	39.9	45.4	58.8	77.2
50	27.9	30.0	32.3	35.1	38.5	43.8	56.0	72.9
55	27.2	29.2	31.5	34.1	37.3	42.4	53.7	69.5
60	26.6	28.5	30.7	33.3	36.4	41.2	51.9	66.7
65	26.1	28.0	30.1	32.6	35.5	40.2	50.4	64.5
70	25.7	27.5	29.6	32.1	34.9	39.5	49.2	62.8
75	25.4	27.1	29.2	31.6	34.4	38.9	48.4	61.5
80	25.1	26.9	28.9	31.3	34.0	38.4	47.7	60.6
85	25.0	26.9	28.7	31.1	33.8	38.2	47.4	60.1
90	25.0	26.9	28.7	31.1	33.8	38.1	47.3	59.9

3.0 A SUMMARY OF TEST RESULTS

The SST jet noise program was divided into two parts: a low noise-suppression effort (≥5 PNdB suppression) and a high noise-suppression effort (12 to 20 PNdB suppression). The low noise-suppression effort and results are covered only briefly in this section because this information is already well documented elsewhere (refs. 6, 7, 8, 9, and 10). Full-scale tests of the GE4/J5P engine with the two-stage ejector-nozzle (TSEN) installed indicated that the prototype SST could meet the FAA objective of 116 PNdB peak noise level at the 1500-ft sideline during takeoff. This obviated the need to continue on with the low noise-suppression effort. In 1968, the full resources of the SST jet noise staff were applied to the problem of developing a 12- to 20-PNdB jet noise suppressor for use on the commercial version of the SST. More emphasis has been placed on results of the 12- to 20-PNdB suppression effort in this section because the results have not been well documented at this date.

3.1 LOW NOISE-SUPPRESSION (5 PNdB) PROGRAM

3.1.1 Model-Scale Testing

Model-scale nozzle acoustic testing was conducted at the Boeing Annex D jet noise facility located in the Boeing Plant II area complex in Seattle. Model-scale nozzle testing was based on the premise that jet noise characteristics can be scaled on a dimensional basis. This hypothesis had been fairly well established by considerable acoustic data acquired by many independent jet noise research programs (see ref. 11 for an example). Most nozzle configurations tested were eighth-scale replicas of candidate jet noise suppressor systems for the GE4/J5P turbojet and P&WA 17A-21B turbofan engines proposed as the propulsion units for the prototype supersonic transport. For eighth-scale acoustic tests, the 25-ft polar arc microphone layout was representative of a 200-ft polar arc layout full scale. The jet noise spectrum has to be adjusted in frequency by a factor of eight to be representative of full-scale nozzle test results (e.g., 8 kHz for eighth-scale nozzle corresponds to 1 kHz for full-scale nozzle).

Model-scale testing was an economical method of testing a large number of suppressor nozzle configurations. The desired primary flow conditions could be obtained on the model nozzle test facility, whereas an actual turbojet engine capable of approaching the engine conditions proposed for the SST did not exist. A disadvantage in the initial model test program was the lack of suppressor nozzle performance data to relate nozzle propulsion values with acoustic noise suppression results. Later in the SST jet noise program, a facility to acquire accurate thrust values simultaneously with acoustic data was developed to overcome this deficiency.

Three categories of nozzles were tested in 1966 at the Annex D jet noise test facility. The first group of nozzles was selected from previous jet noise test programs to ascertain jet noise characteristics under supersonic jet flow conditions. These nozzles were various multitube and multispoke configurations described in appendix A, section A.1. The tube nozzles tested (9, 21, and 37 tubes) showed perceived noise suppression values greater than 5 PNdB; however, these nozzle systems would exact a large performance penalty during

supersonic cruise unless they could be retracted and stowed after the airplane cleared the community. A jet noise suppressor system of this type was considered to be impractical for the prototype SST.

Tests of spoke nozzle configurations, where the number of spokes was four, six, or eight and spoke penetration of the flow was 20%, 50%, or 75%, indicated that perceived noise level (PNL) suppression improved as the number of spokes increased and as the spoke depth of penetration of the primary flow increased (ref. 19). The resolution of these early tests was not very good since only three microphone positions were used 30°, 45°, and 60° relative to the jet axis and nozzle exit).Subsequent testing indicated that 5° or 10° increments between microphone positions was necessary to attain maximum perceived noise levels with 1-2 PNdB accuracy. Acoustic measurement techniques evolved during the 5-year jet noise suppression program resulted in good data resolution and better control of sound propagation anomalies.

Emphasis was placed on testing of various "lobed" primary nozzles with ejectors outfitted with different types of "chutes" or "scoops" (see app. A). The primary nozzle was designed to provide the initial suppression of jet noise, while the chuted ejector surrounding the fully expanded flow would provide an additional stage of suppression.

Primary nozzles applicable to the proposed GE turbojet and P&WA turbofan engines were tested. These nozzles varied from four-lobe to 16-lobe configurations with flow penetrations of 12% to 50% (see app. A, sec. A.1). The primary nozzles tested provided 0.5 to 3 PNdB suppression at the maximum nonaugmented power settings (see ref. 20).

The chuted ejector configurations tested showed higher suppression values. Jet noise suppression up to 6-8.5 PNdB was demonstrated. Chutes in the ejector penetrated into the fully expanded flow to induce jet mixing with ambient air pumped into the inlet of the ejector by the jet. This increased mixing concept was designed to lower the velocity of the exposed jet beyond the ejector exit.

Scoops were different from chutes in that the scoops enabled ambient air from openings in the ejector sidewall to mix with the jet as well as ambient air from the ejector inlet. Scoops did not prove as effective as chutes in suppressing jet noise.

The model-scale 5-PNdB suppressor program during 1967 was an intensive effort to determine the parametric relationships pertinent to chuted-ejector noise suppression and to determine near-optimum configurations. Five primary nozzle types, 15 ejector types, and 28 chute types were tested in about 70 different combinations (see app. A, sec. A.2). Test conditions were generally T_T = 3000 R (2540° F) with pressure ratios ranging from 2.0 to 3.3. Acoustic data were recorded on a 25-ft polar arc in 10° increments from 40° to 80° relative to the jet axis.

Model-scale testing indicated little difference in noise suppression in the use of chutes of different shapes, i.e., conical chutes performed as well as flat chutes. Jet noise suppression increased with an increase in chute angle of attack and blockage ratio. Suppression decreased

as primary gas pressure ratio increased when the ejector-to-primary-nozzle area ratio was small ($A_E/A_P < 2.0$), see figure 15 (from ref. 7). Suppression tends to be independent of chute penetration when angle of attack and blockage ratio were held constant. Longitudinal positioning of the chutes indicated chutes were more effective when positioned nearer to the primary nozzle, see figure 16.

The chuted ejector configuration considered to have the best noise suppression characteristics tested attained the following PNL suppression values, referenced to the 1500-ft sideline with a primary gas temperature of 2540°F.

Pressure Ratio	PNL Suppression (ΔPNdB)
2.7	8.0
3.0	10.1
3.3	10.1

This configuration had a 4.1-in.-diameter primary nozzle. The cylindrical ejector (designated E9) had a diameter of 6.35 in. and length of 9.1 in., see figure 17. The ejector inlet diameter was 7.3 in. Eight flat chutes 0.45 in. wide and 1.5 in. long were set 1.5 in. upstream of the ejector throat, e.g., 0.75 in. downstream of the primary nozzle exit plane. The chute angle of attack was 37.4°. Chute penetration was 40% of the jet flow, see references 21 and 22.

3.1.2 Full-Scale Testing

Full-scale nozzle testing used the YJ-75 engine since acoustic information concerning jet noise suppressors was needed at afterburning turbojet engine conditions. Unfortunately, the primary gas conditions achieved by the YJ-75 engine did not approach the conditions anticipated for the SST propulsion system. The nozzle pressure ratio in particular fell considerably short of the desired primary gas conditions.

Initial tests were conducted at the North Boeing Field (Seattle), Mechanical Laboratory test area. The jet noise suppression hardware items tested were largely full-scale equivalents of promising configurations tested at the model-scale test facility. A round convergent primary nozzle and a 16-pointed star nozzle were tested with various chuted (or scooped) ejector configurations. Also, a four-lobe primary nozzle was tested without an ejector. Primary gas conditions at the nozzle were total temperatures of 1020° and 2880°F and pressure ratios of 2.5 and 2.2 (see app. A, sec. A.3). Acoustic data were recorded at angles of 30° to 90° (in 10° increments) relative to the nozzle exit and jet axis. Microphones were located on a 200-ft polar arc. Engine performance data were recorded simultaneously with acoustic data. A description of the tests performed, together with the recorded acoustic and performance data, can be found in reference 8.

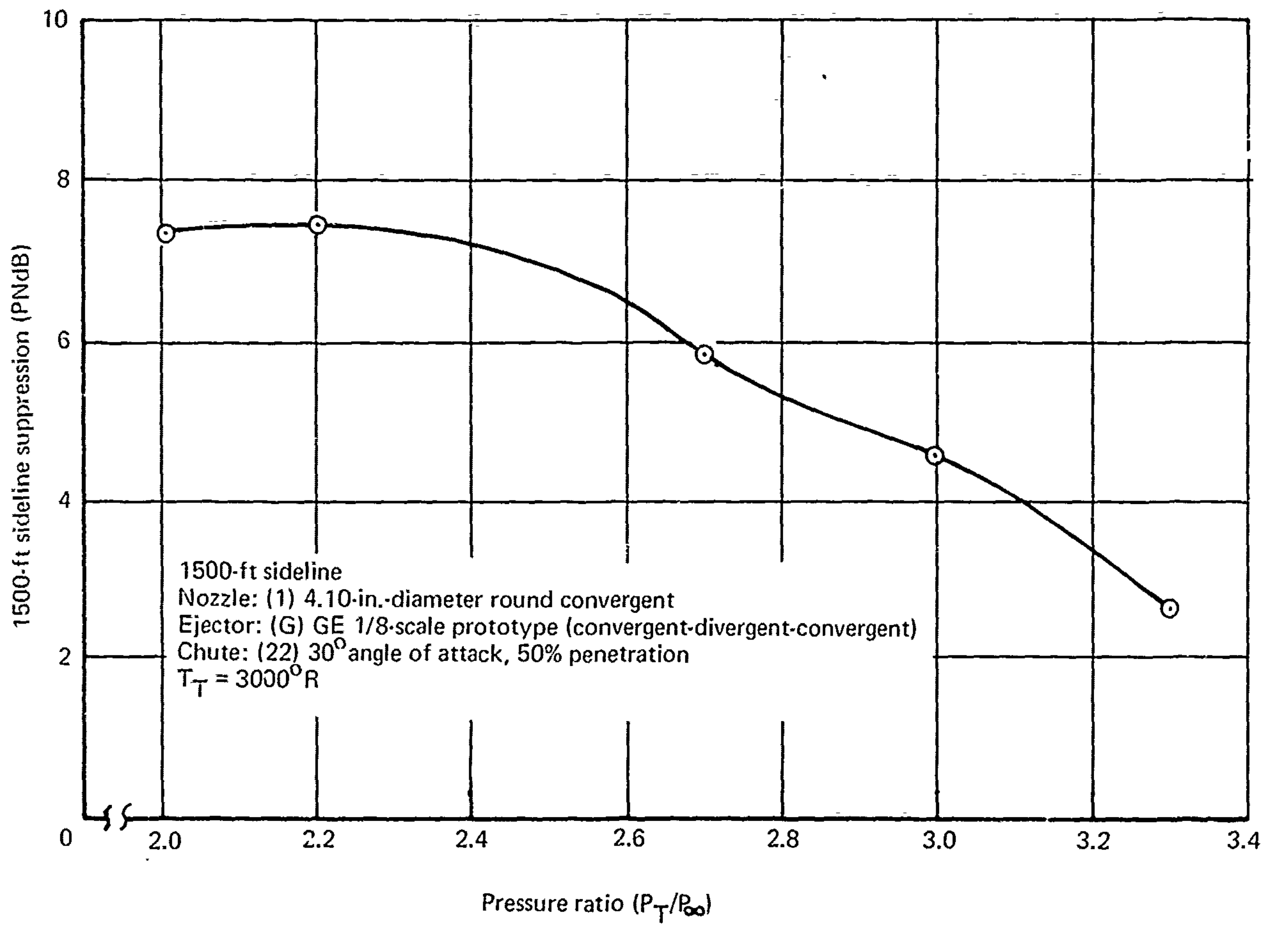
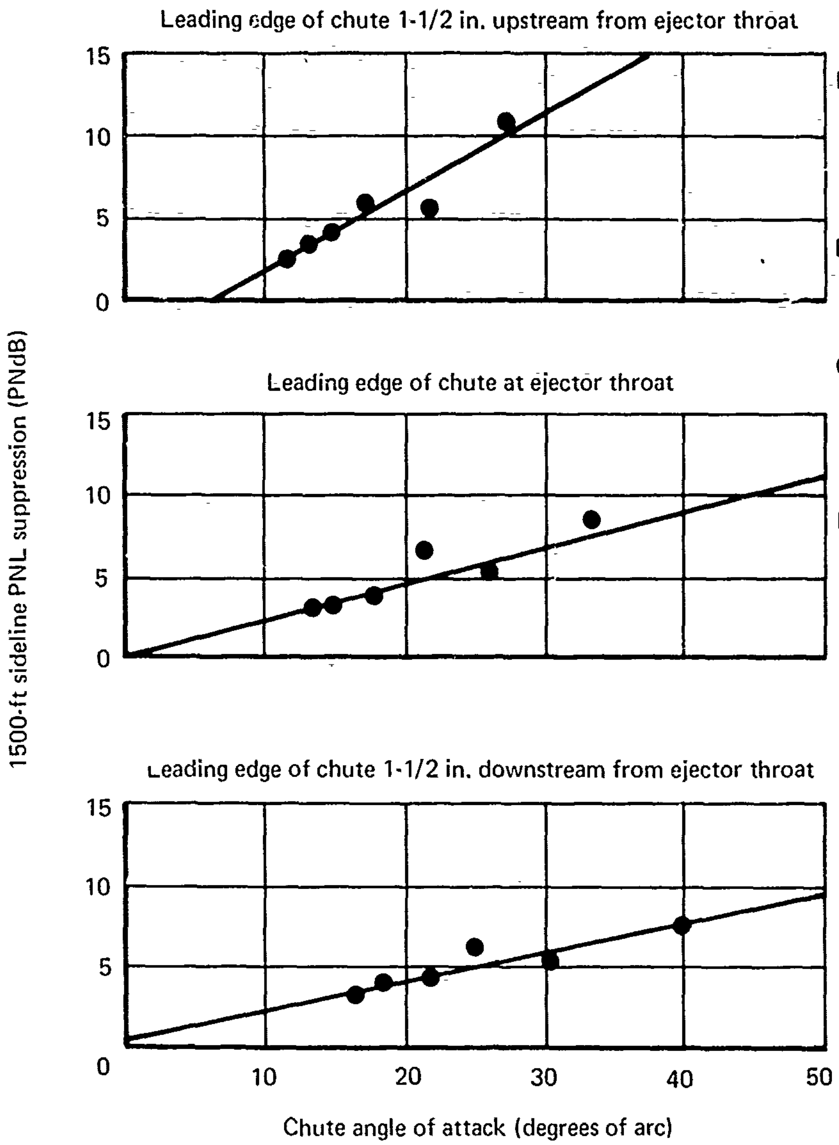


FIGURE 15.—EFFECT OF PRESSURE RATIO ON SUPPRESSION, FLAT CHUTES WITH SIDES
Scale Model Test Facility (Annex D)



Nozzle:
Round convergent, 4.1-in. exit diameter

Ejector:
Cylindrical, 1.55 ratio

Chutes:
Flat with sides 0.45 in. wide, 40% penetration

Nozzle pressure ratio:
3.0

Total temperature:
3000 R

Nozzle:
Throat distance = 2-1/4 in.

FIGURE 16.—CHUTE POSITION STUDIES

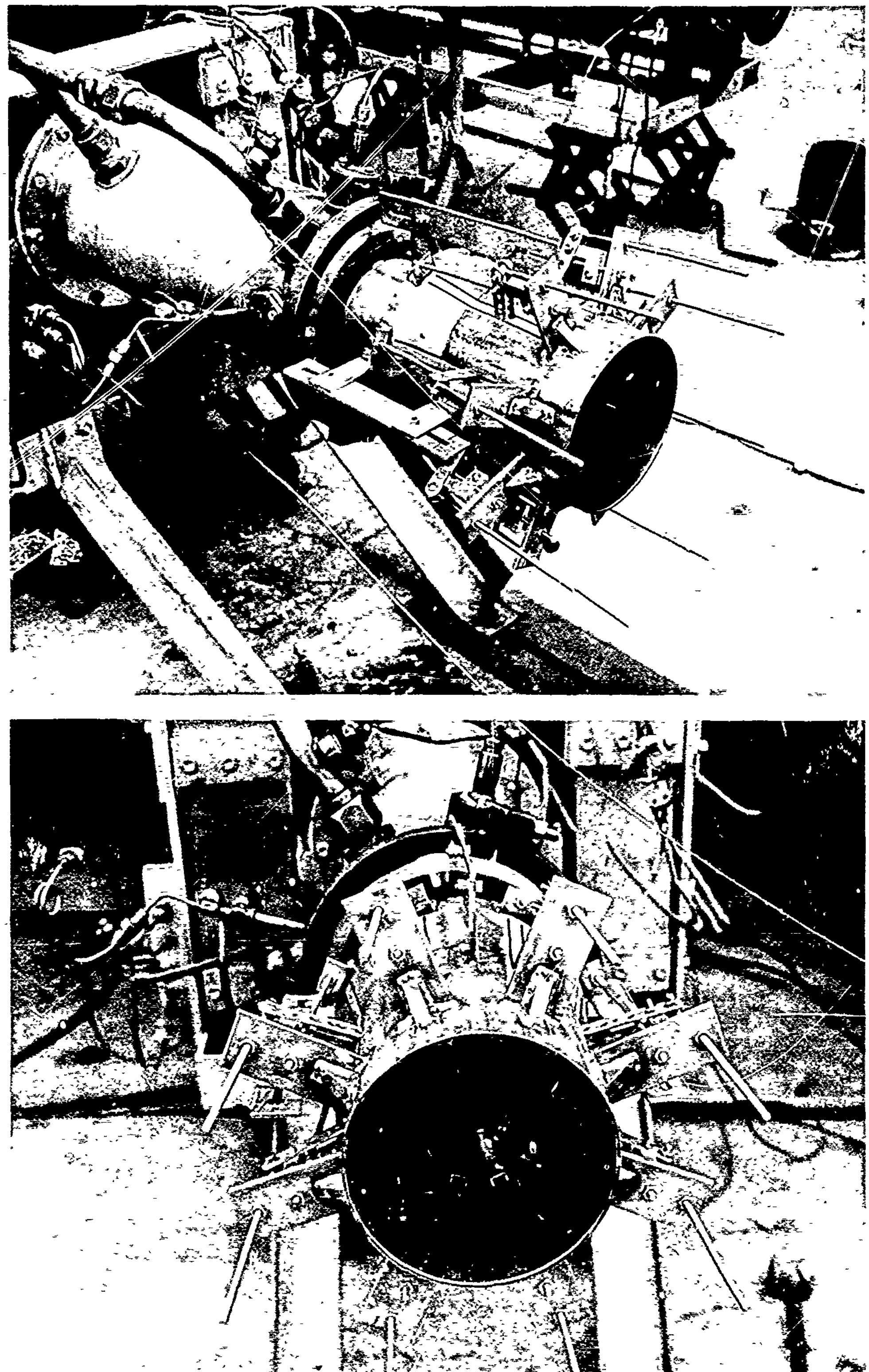


FIGURE 17.—4.1-IN. ROUND CONVERGENT NOZZLE WITH E9 EJECTOR

At the afterburning engine conditions, where PR = 2.2 and T_T = 2880°F, the following PNL suppression and thrust loss values were determined:

Nozzle Configuration	PNL Suppression (PNdB)	Thrust Loss (%)
Four-lobe primary nozzle	5.0	0.0
Ejector[a]	1.0	0.8
Ejector[a] eight chutes 30% penetration	4.0	4.4
Ejector[a] eight chutes 44% penetration	7.0	7.6
Ejector[a] eight scoops 37% penetration	5.0	6.7

[a]Round convergent primary nozzle used.

Other acoustic results are discussed in references 23 and 24. All Boeing SST program full-scale nozzle testing after 1966 was conducted at the Boardman facility.

The next series of full-scale nozzle tests was more involved in ejector and chute (and scoop) parametrics. Several chute widths were tested with penetration of the jet as a variable—e.g., 30%, 40%, and 50% penetration of the flow. Primary flow conditions were total temperatures of 2910° to 3190°F and pressure ratios of 1.9 to 2.2. The YJ-75 engine was used for these tests. The configurations tested are listed in appendix A, section A.4.

The noise-suppressor configuration that yielded the best results during this test series used eight chutes 3.6 in. wide installed in the ejector so as to achieve 40% penetration of the jet flow. Test results are:

PR	T_T (°F)	V_J(ideal)(fps)	PNL Suppression (PNdB)	Thrust Loss (%)
1.9	2910	2640	8.5	5
2.0	3080	2800	8.0	6
2.2	3190	3020	5.0	7

Scoops tended to provide less PNL suppression for an equal amount of thrust loss than did chutes. A complete account of noise and performance characteristics is contained in reference 25.

The third series of full-scale tests used a round convergent nozzle, a 16-pointed star nozzle, and a four-lobe nozzle with ejectors of several different sizes. Various kinds of chutes were tested—flat chutes with sides, conical chutes, box chutes, and wing chutes. Chute lengths were either 17.3 or 27.8 in. Chute flow penetration was 40% in most cases. The YJ-75 engine was used in the afterburning power settings with total temperatures of 2900° to 3200° F and nozzle pressure ratios of 1.84 to 2.20. Configurations tested are listed in appendix A, section A.5.

Chute shape did not influence noise suppression. When chute angle of attack was increased from 15.6° to 25.5° with 40% flow penetration, there was a 1.5-PNdB improvement in noise suppression; however, thrust loss increased. PNL suppression and thrust loss decreased almost linearly as the number of chutes in the ejector was decreased.

A divergent ejector provided 3 PNdB more suppression than a cylindrical ejector, however static thrust loss increased 2%. A 1-in.-thick fiberglass-lined ejector did not enhance PNL suppression values because of low-frequency dominance in the spectrum. However, from 710 to 11,200 Hz there was a 3- to 9-dB decrease in spectrum level due to the acoustic absorptive lining.

The 16-point star nozzle with 12% penetration of the primary flow showed no value as a suppressor nozzle. The four-lobe nozzle with 50% flow penetration attained 4 PNdB suppression with 0.5% to 1% thrust loss. Descriptions of the third series of full-scale, 5-PNdB program testing with test results have been reported in reference 9.

The fourth series of full-scale tests used contoured ejectors: chute length, penetration, longitudinal positioning, and angle of attack were varied. A YJ-75 engine with afterburner was used with total temperatures of 3010° to 3220° F and nozzle pressure ratios of 1.93 to 2.28. Configurations tested are listed in appendix A, section A.6.

The contoured E1 ejector ($D_E/D_T = 1.00$), with eight chutes mounted at the throat and with a nominal chute penetration of 40%, gave suppression values on the order of 4 to 5 PNdB. Variations of chute orientation (angle of attack or penetration) produced changes in the suppression on the order of 1.5 PNdB. While no general correlation appeared between changes in angle of attack and changes in suppression, increases in chute penetration resulted in suppression increases. Thrust loss, on the other hand, showed a definite increase as either penetration or angle of attack increased. With the chute mounted at a nominal penetration of 40%, thrust loss (based on a round convergent reference nozzle) varied from about 3.5% for a 16° angle of attack to about 12.5% for a 36° angle of attack.

As a result of the behavior of suppression and thrust loss relative to changes in chute orientation, the ratio of PNL suppression to thrust loss decreases as either chute penetration or angle of attack increases.

The contoured, divergent, E2 ejector ($D_E/D_T = 1.15$) gave suppressions that ranged from 7 to 9.5 PNdB, while thrust loss ranged from about 10% to nearly 25%. With eight chutes mounted at the throat and with a nominal penetration of 40%, suppression ranged from about 7 PNdB for an angle of attack of 16°, to 8 PNdB for an angle of attack of 24°. The corresponding change in thrust loss varied from 10% to 13%.

Those configurations in which the chutes were mounted forward of the ejector throat at 40% penetration yielded suppression values of 9 to 9.5 PNdB, while thrust loss varied from 16.5% to 20%.

Changing the orientation of the chutes mounted forward of the throat produced suppression changes on the order of 1 PNdB, but the change appearing in thrust loss were severe. As an example eight chutes at 30% penetration and 29° angle of attack gave 14% thrust loss, while eight chutes at 50% penetration and a 38° angle of attack gave a 25% thrust loss.

There was negligible effect on suppression when two of the chutes mounted forward of the ejector throat, E2, were removed. Thrust loss decreased from 20% with eight chutes to 16% with six chutes.

The use of the blow-in-door simulator had little effect on the suppression or thrust loss obtained with ejector E1. No study was conducted to determine the effects of a blow-in-door simulator with ejector E2.

In addition to the studies made with the engine operating in the afterburning mode at high nozzle pressure ratios (1.93, 2.11, and 2.28), a study was carried out to investigate the suppression and performance characteristics of chuted ejectors at low nozzle pressure ratios (1.1, 1.2, and 1.5). It was found that suppression decreased sharply to less than 2 PNdB at the lower pressure ratios. Thrust losses generally did not show correspondingly great reductions, so that the ratio of PNL suppression to thrust loss was less at the three low pressure ratios than at the three high pressure ratios.

3.2 HIGH NOISE-SUPPRESSION (12-20 PNdB) PROGRAM

3.2.1 Model-Scale Testing (Chronicle)

Model-scale suppressor nozzles tested in 1967 at the Boeing Annex D facility (Plant II complex) are included in appendix B, section B.1. Spoke nozzles were tested with number of spokes, spoke penetration, area ratio, and exit cant angle among the variables investigated. Multitube nozzle configurations were oriented toward 37-tube arrays where equal spacing between adjacent tubes was maintained. Area ratios tested varied from 3.33 to 8.0. Some configurations had tubes with round convergent terminations while others had 12-spoke ends on each tube. At pressure ratios of 3.0 or higher, the multitube suppressor nozzles tended to maintain good PNL suppression values whereas spoke nozzle suppression tended to deteriorate significantly. Since there was so little information available concerning the suppression of supersonic jet noise, several novel design concepts were tested using the "shotgun" approach to the problem. One nozzle, designated HM-AP-6, had six radial arms with 20 parallel slots in each arm. A maximum suppression of 12.5 PNdB was attained with this nozzle; however, the static thrust loss was excessive. Another nozzle tested had seven tubes coupled to the atmosphere and surrounded by the primary flow (HM-AP-23). The HM-AP-23 nozzle attained 6.5 PNdB suppression with 1% thrust loss, relative to a round convergent reference nozzle. This transposition of flow elements provided good noise characteristics at high pressure ratios and with a low area ratio (AR = 1.8). The results of performance testing conducted during this time period on annular and multitube annular suppressors (HM-P-1 through -9) are shown in reference 25.1 and summarized in appendix D.

The 1968 model-scale suppressor nozzle test program continued the multispoke and multitube parametric studies initiated in the previous year. During this period, the hot nozzle test facility (HNTF) at the Boeing Mechanical Laboratory complex (north end of Boeing Field) was completed. This facility provided accurate static thrust data simultaneously with the jet noise measurements. The thrust information was invaluable by providing a check on mean indicated total temperature and other gas conditions. A method eliminating ground reflection interference introduced at the HNTF provided free-field acoustic data. Previously, ground reflection interference seriously hampered spectrum analysis and affected the accuracy of extrapolated PNL values.

The suppressor nozzles tested at Annex D during 1968 are listed in appendix B, section B.2. Some of the nozzles of interest tested during this period were: annulus slot with center plug shaped for attached flow (HM-AP-20), 60 radial slots with annular configuration (HM-AP-36), combination tube and spoke nozzles, 37 tubes for tertiary air surrounded by primary flow (HM-AP-56), rectangular multitube arrays and ejector configurations.

Suppressor nozzles tested at the HNTF during 1968-69 are listed in appendix B, section B.3. The multitube nozzle parametric study was broadened by testing 126-tube (HM-AP-85) and 330-tube (HM-AP-86) hexagonal arrays. Also, the 37-tube nozzle study was extended into the augmented flow total-temperature region 1500° to 3000° F in the testing of Cr-Ti-Si coated columbium nozzles (HM-AP-55).

A 36-spoke nozzle (HM-AP-45) with an area ratio of 2.06 was tested at the HNTF. A full-scale version of this nozzle, designated HL-AP-9, was tested at Boardman, Oregon on the J-93 engine. The model-scale and full-scale nozzle test data showed very good agreement (see ref. 11). Several propulsion design nozzle systems were tested at the HNTF, notably a combination array of 16 spokes and 16 clusters of tubes (HM-AP-78), a 97-tube array (NSC-82), and a 61-tube array (NSC-119B). The propulsion and acoustic data acquired from testing the NSC-119B nozzle indicated that this concept would meet FAR 36 requirements when applied to the production version of the SST.

Jet noise characteristics of the various suppressor nozzle configurations tested in the SST jet noise program emphasized supersonic flow with conditions ranging from $0.85 < M_J < 1.56$, e.g., pressure ratios from 1.6 to 4.0. Gas total temperatures investigated varied from ambient to 3000° F, although very limited data were obtained at the extreme conditions of temperature. The gas condition of prime interest was T_T = 1500° F and PR = 3.0, which represented, approximately, the maximum dry-engine (nonafterburning) power setting for the GE4/J5P engine.

Later in the program, increasing emphasis was placed on higher bypass ratio turbojet engine configurations such as the GE4/J6G and then the GE4/J6H2 proposed engines. At takeoff aircraft velocities of 200 to 230 kn, higher pressure ratios (3.4 to 3.8) were important, and suppressor nozzles deemed adequate for the original maximum dry-engine conditions turned out to be inadequate in obtaining the desired noise levels at the later imposed conditions.

3.2.1.1 Research Technique

The research technique used almost exclusively during the SST jet noise program was the testing of many different kinds of suppressor nozzle configurations (both model scale and full scale) and measuring the jet-radiated acoustic noise in the far field. The acoustic data acquired were extrapolated to the 1500-ft sideline (later to the 2128-ft sideline) and perceived noise levels (PNdB) were determined using SAE-approved methods.

The main objective of the SST jet noise program was to determine the subjective efficacy of suppressor nozzle concepts. This information determined whether the propulsion and noise-suppressor system, as installed on the SST, would meet established subjective acceptance levels. Evaluation of jet noise suppressor concepts in subjective units of PNdB provides no information concerning the mechanisms of noise generation. The secondary goal of the program was to conduct an evaluation of jet suppressor nozzle noise characteristics using unextrapolated, measured data.

Analyses of radiated far-field acoustic noise spectrums, noise beam patterns, and performance results using such variables as primary gas conditions; number, size, and shape of flow elements; relative distance between flow elements (variations in area ratio); jet cross-section configuration, etc.; provided the methods to inductively determine the characteristics of multijet noise generation. The mechanized model of jet noise generation established by these inductive methods provided the general rules and guidelines for developing suppressor nozzle concepts.

The generalizations set forth in this document warrant further investigation. There are other research tools and methods available that can be applied to further delineate the mechanized model of suppressor nozzle jet noise generation.

3.2.1.2 Noise Suppression Rationale

There are two relationships in jet noise research that serve as guides in understanding suppressor nozzle noise generation. One relationship derived from the Lighthill equation is where

$$\text{Acoustic power} = \frac{K\rho^2 AV^8}{\rho_o a_o^{\,5}}$$

where

ρ = density of fully expanded jet

ρ_o = density of surrounding medium

a_o = speed of sound in surrounding medium

A = cross-sectional area of jet

V = efflux velocity of jet

K = dimensionless constant

Although this equation was meant to describe simple subsonic jet noise generation, the factors of gas density (ρ), flow area (A), and jet velocity (V) were recognized to be key variables in jet noise research when atmospheric conditions are held relatively constant. The other relationship used was the Strouhal number, which is equal to fD/V. The Strouhal number relationship served as a guide in understanding the frequency content in acoustic noise spectrum analyses. The dimension (D) is considered to be directly related to the width of the jet mixing region. The peak frequency observed in the spectrum of a simple jet is generally recognized as being equal to 0.22 V/D when sound pressure levels are expressed in terms of constant percentage bandwidths, i.e., octave or third-octave band levels. In subsonic flow, the peak levels are considered to be radiated from the mixing region adjacent to the end of the jet potential core. In supersonic jets, the peak level occurs some distance beyond the potential core, this distance being related to the Mach number (M_J) of the primary flow.

Multitube and multispoke suppressor nozzles were observed to have a random noise spectrum that had a low-frequency peak and a high-frequency peak. This spectrum was considered to be a composite spectrum. Noise generated in the jet mixing region prior to the coalescence of the individual jets into a single jet is considered to be responsible for the high-frequency peak. This conclusion was derived by evidence compatible with the Strouhal number relationship to the exit diameter of individual tubes in a multitube array. An example is shown in figure 18 (see ref. 26).

Since multielement nozzles significantly shorten the jet mixing region relative to the jet efflux from an equivalent-area round nozzle, the mixing region can be completely surrounded by an ejector. The inner wall of an ejector can be treated to absorb noise radiated from the jet mixing region. Tests of ejectors lined with acoustically absorbent material and installed on various multielement nozzles have consistently shown significant suppression of the high-frequency peak portion of the spectrum. This supports the hypothesis that high-frequency noise emanates mainly from the jet mixing region.

The low-frequency peak in the multielement nozzle acoustic spectrum was also thought to be compatible with the Strouhal number relationship. The coalesced jet contains a considerable amount of secondary flow entrainment from the mixing process; therefore, the relatively large, low-velocity coalesced jet would be expected to have a noise spectrum that peaks at the low-frequency end of the spectrum.

Figure 19 shows schematically the relationship believed to exist in the composite multielement nozzle jet noise spectrum. The high frequencies are dominated by noise radiated from the jets prior to coalescence. The low frequencies are dominated by noise radiated from the coalesced jet. The existence of another defined mixing region in the coalesced jet has been hypothesized and could be verified by determining the velocity profile in this region experimentally.

Various types of suppressor nozzles tend to attain peak PNL suppression values at jet velocities between 2100 and 2600 fps. This trend is evident in figure 20. There also was a tendency for suppression to fall off rapidly at jet velocities below 2100 fps, approaching 0 PNdB suppression at jet velocities between 1200 and 1600 fps. Not many measurements were taken at ideal jet velocities less than 1600 fps during the SST program, and jet noise characteristics in this velocity region were ill-defined by this program.

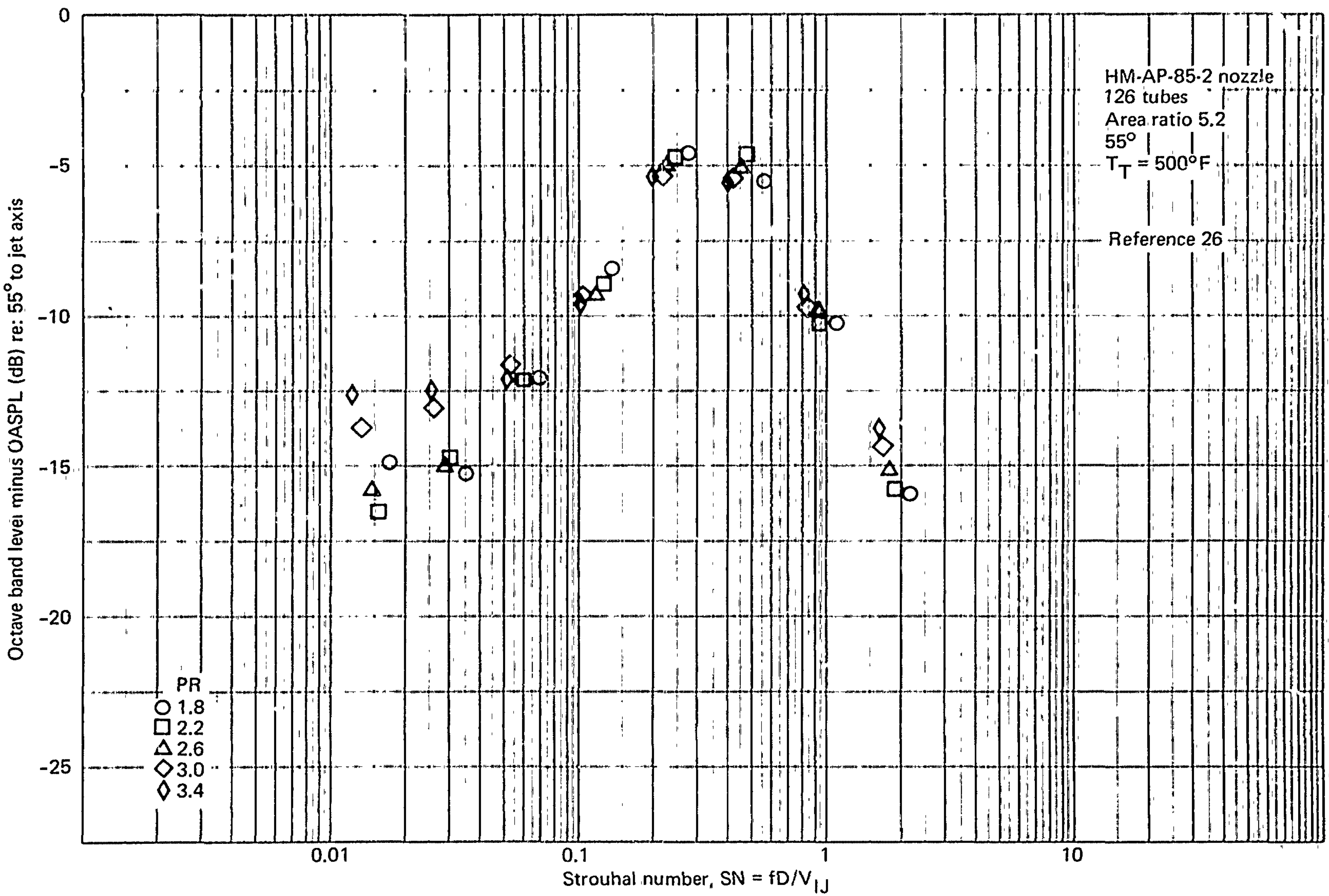


FIGURE 18.—MULTITUBE NOZZLE JET NOISE SPECTRUM RELATIONSHIP TO STROUHAL NUMBER

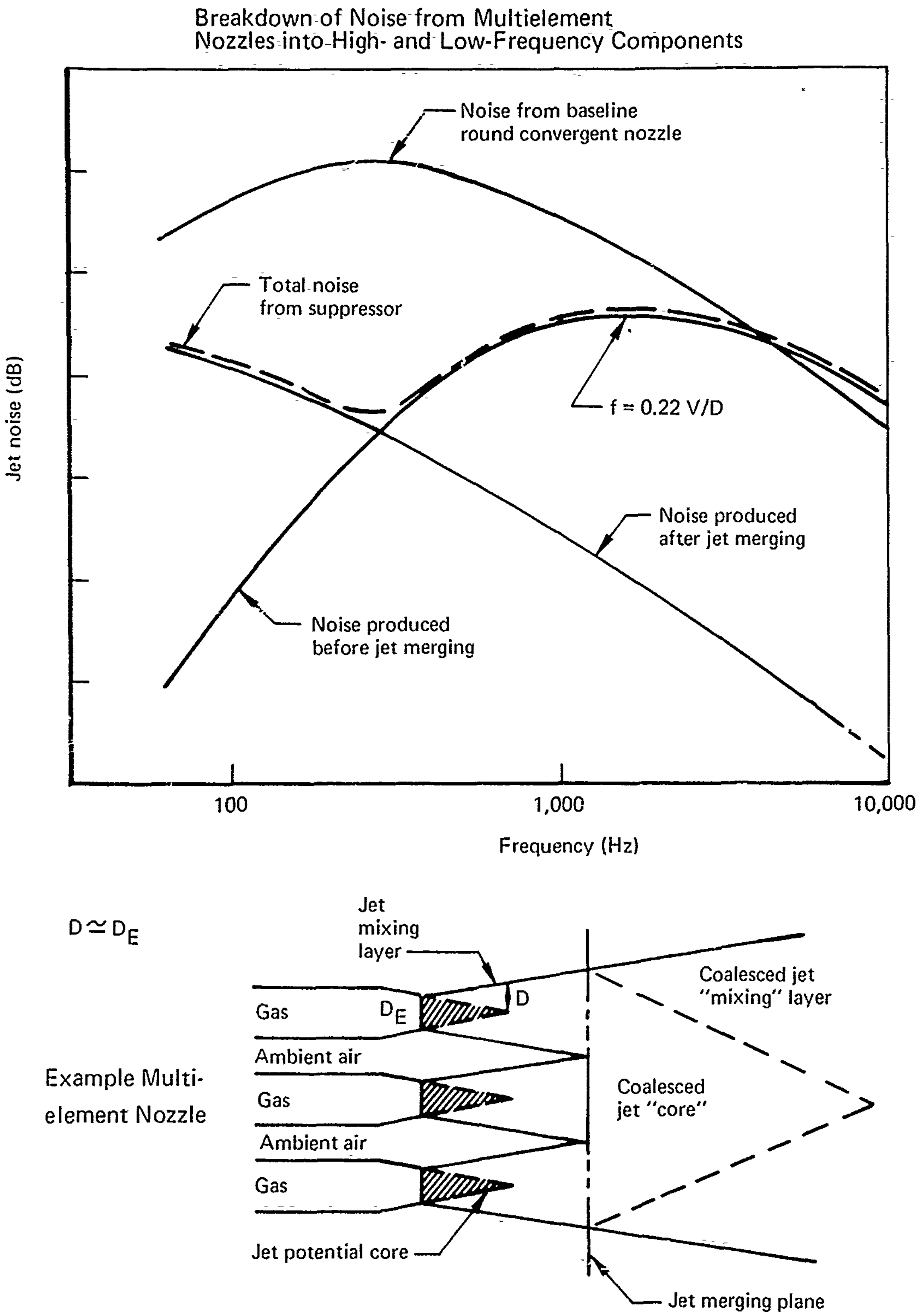
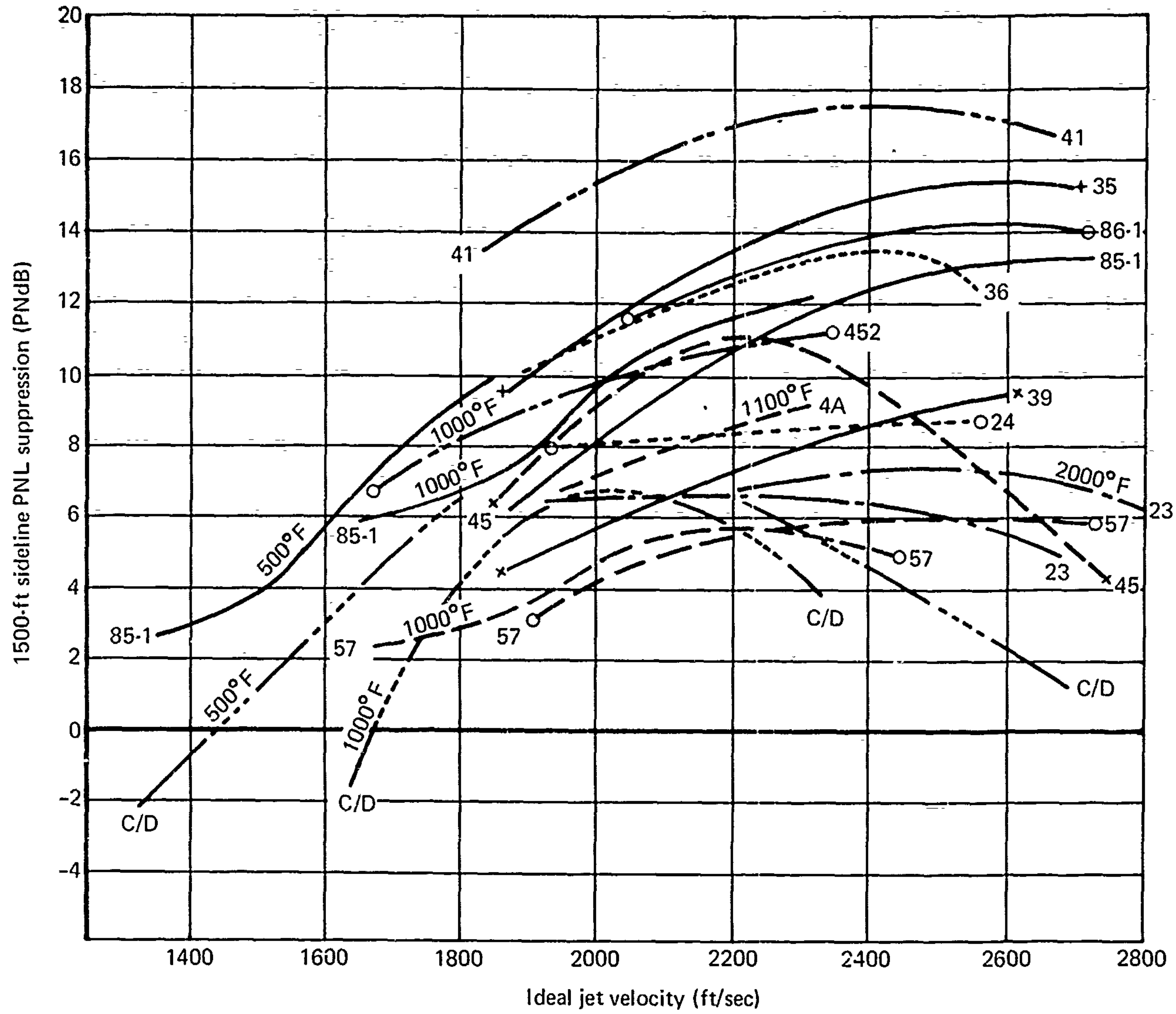


FIGURE 19.—MULTIELEMENT NOZZLE JET NOISE SPECTRUM



O--------O	HM-AP-24	Five parallel slots, AR 3.0
—— – ——	HM-AP-23	Seven tubes (internally ventilated), AR 1.8
+——————+	HM-AP-35	270-tube hexagonal annulus array, AR 7.0
----------	HM-AP-36	Annulus array of 60 slots, AR 5.0
×—— —— ——×	HM-AP-45	36 spokes, AR 2.06
O—— —— ——O	HM-AP-57	12 spokes, AR 1.86
—— —— ——	MAE 4A	12 spokes and center plug, AR 2.9
——·---·——	C/D nozzle	$A_E/A^* = 1.635$ (M_J 1.92)
—— – – ——	HM-AP-41	37 tubes with 12 spoke ends, AR 4.0
O——————O	HM-AP-86-1	330 tubes, AR 4.0
————————	HM-AP-85-1	126 tubes, AR 3.33
×——————×	HM-AP-39	37 tubes, AR 4.0
O—·--·—O	MPP 452	21 tubes (six spoke ends on outer row of tubes), AR 2.6

T_T = 1500°F except where noted otherwise

FIGURE 20.—EFFECT OF JET VELOCITY ON PNL SUPPRESSION FOR VARIOUS SUPPRESSOR NOZZLE TYPES

The improvement of noise suppression with an increase in jet velocity may be due to the change in physical properties of eddies in the jet mixing layer. The turbulence at the outer periphery of flow appears to "mask" or "shield" the noise generated by flow elements within the array. This "masking" effect has been attributed to (1) a redirection of acoustic energy by scattering, (2) absorption of acoustic energy, or (3) inhibition of the generation of acoustic energy.

Figure 21 (from ref. 27) shows the amount of suppression attained with multitube nozzle arrays at primary gas conditions of $T_T = 1500°$ F and PR = 3.0 [V_J (Ideal) = 2550 fps]. The number of tubes in these nozzle arrays varied from 37 to 330. The overall sound pressure levels were integrated over a polar arc from 40° to 80° relative to the jet axis and compared with the integrated SPL from an equivalent-area round convergent nozzle jet (ref. 27). Although the propulsion power is approximately the same, there is a definite decrease in radiated acoustic energy as the number of tubes in the array is increased. A relationship is shown in figure 21 where OASPL suppression is proportional to the ratio of the total number of tubes in the array to the number of tubes occupying a 60° sector in the outer row of tubes. This curve approximates the results obtained from the tests, lending support to the hypothesis that the outer jet elements provide the radiated acoustic power and substantially shield the noise generated within a multitube nozzle array.

The OASPL (average) suppression reaches an optimum value at some jet velocity then diminishes as shown in figure 22 for 126-tube arrays. The drop in OASPL suppression at the higher jet velocities is largely due to an increase in the low-frequency part of the acoustic spectrum. Arrays that have a close spacing of tubes (small area ratios) will peak in suppression at a lower jet velocity than those that have tubes spaced further apart. The jet coalescing noise (low frequencies) is believed to be a function of shear when adjacent jet flows combine, and it is not difficult to see that tubes with close spacing will permit adjacent jets to merge earlier where there is considerable kinetic energy, relatively speaking, left in the flow.

The hypothesis that jet shielding of mixing noise and low-frequency noise is a product of jet coalescence was applied to the NSC-119B nozzle. The outer two rows of tubes were spaced relatively far apart (equivalent to an area ratio of 4.0) while the inner tubes were placed relatively close together (equivalent to an area ratio of 2.5). This resulted in an overall area ratio of 2.9, which would hopefully provide satisfactory jet noise suppression characteristics equivalent to an area ratio 4.0 nozzle at the high pressure ratio and jet velocity engine conditions necessary for SST takeoff. The test results were positive lending some credence to our original suppositions (see ref. 28).

A popular belief during the initial part of the SST jet noise program was that good ventilation was necessary with a multielement suppressor nozzle to attain the best jet noise suppression values. This belief was not substantiated in subsequent testing conducted under supersonic flow conditions. Tube and spoke lengths of several models were effectively varied in length by blocking secondary (ambient) flow. There was very little noticeable effect on radiated noise spectrums or beam patterns when the elements were completely blocked or unblocked (see refs. 29, 30, and 31). Large variations in nozzle thrust performance were observed by blocking secondary airflow.

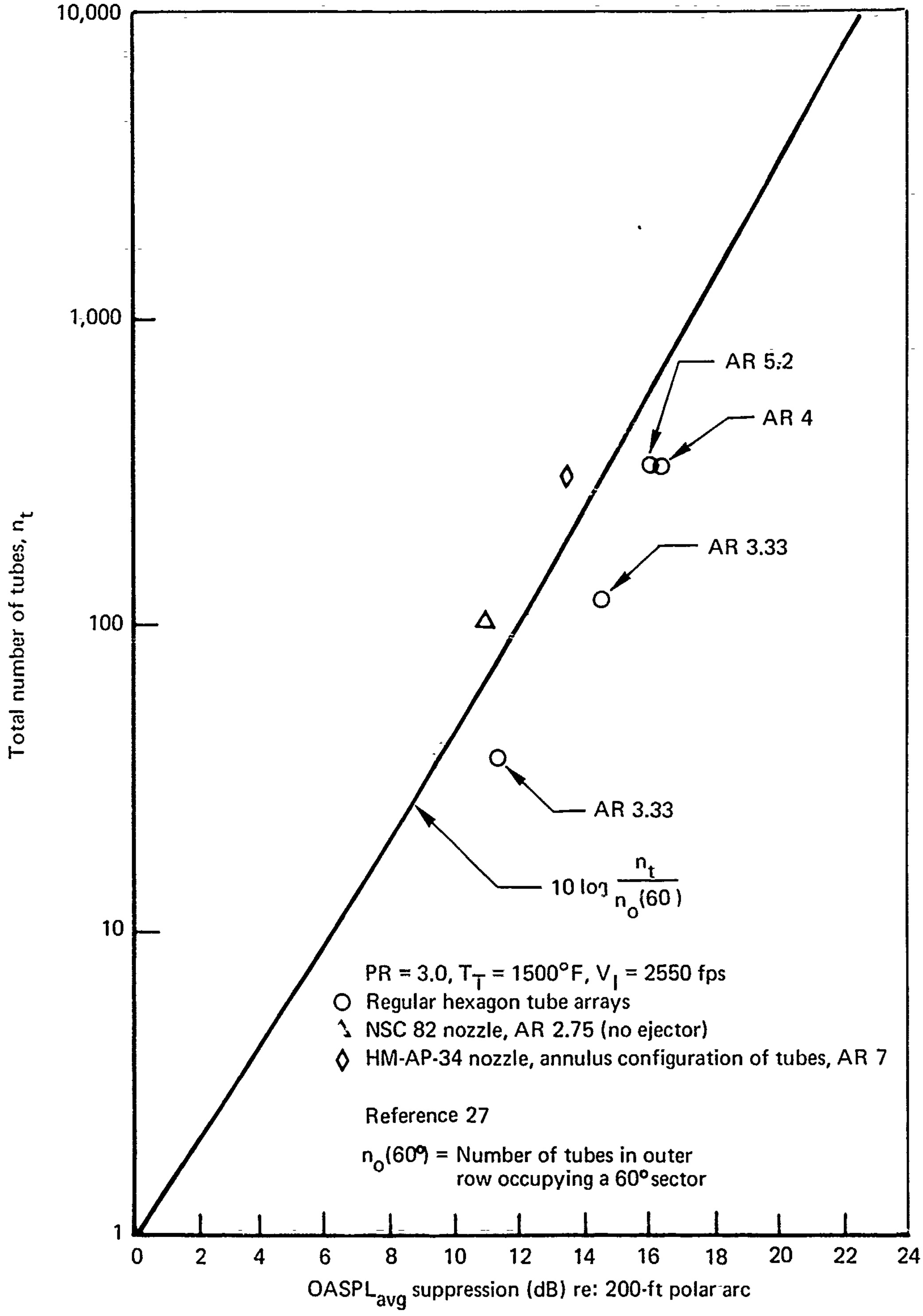


FIGURE 21.—MULTITUBE NOZZLE SUPPRESSION

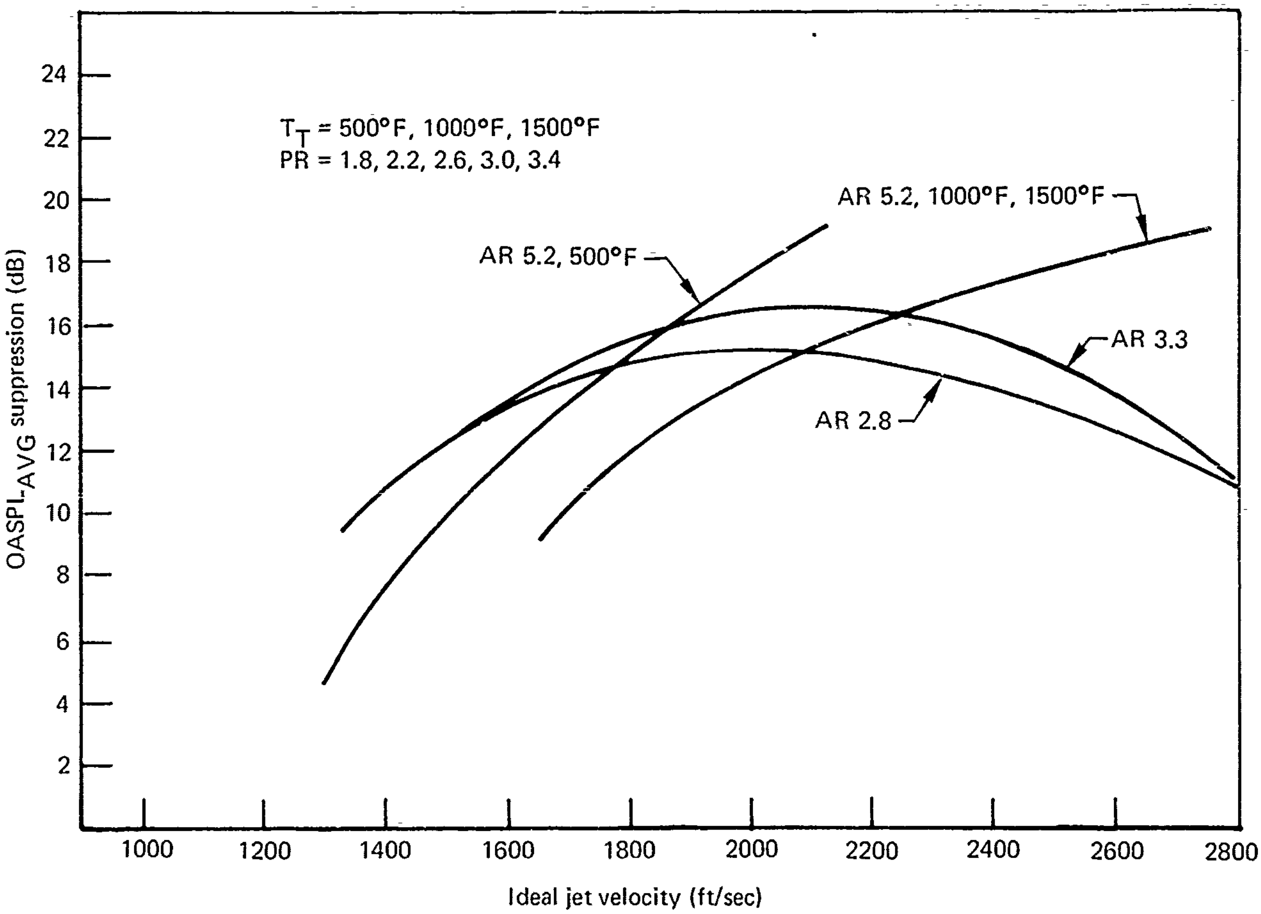


FIGURE 22.—OASPL SUPPRESSION FOR 126-TUBE SUPPRESSOR, 200-FT POLAR

Jet noise tests of a 126-hole, area ratio-2.8, flat plate, resembling a manhole cover and a 126-tube, area ratio-2.8, suppressor nozzle yielded similar results in noise characteristics (ref. 30). However, the difference in thrust loss varied between 15% and 20% for the two nozzles. The range of gas conditions that could be employed using a flat plate multijet nozzle to simulate a multitube array was not determined. The results of this test are sufficiently encouraging to warrant future investigation of the use of flat-plate nozzles in supersonic flow tests. In parametric studies of multielement, coplanar, nozzles, the flat-plate configuration has the potential of supplying the desired acoustic data at substantial savings in nozzle development costs.

Round convergent ends on multitube nozzles did not affect jet noise characteristics when compared to round, straight, nonconvergent ends (ref. 32). Elliptical tube cross sections (major to minor axis ratio of 2) had noise characteristics nearly identical to those of a multitube array comprised of round tube cross sections (ref. 33). The elliptical tubes had their major axes situated in a radial direction reducing the spacing between adjacent jets, radially. This did not result in an increase in low-frequency jet coalescing noise. The peripheral spacing between jets appears to have a more pronounced effect on low-frequency noise generation than does the radial spacing for multitube arrays.

A distinct advantage of multitube nozzles over spoke- or lobe-type nozzles was structural integrity. The high temperatures and pressure ratios used in testing suppressor nozzles, necessitated by GE4 engine conditions, resulted in using materials near the limit of their ultimate tensile strength. Multitube nozzles with their round cross sections invariably survived the extreme gas conditions used in testing with little or no deformation apparent. Two-dimensional configurations, such as spoke, lobe, or slot nozzles, experienced a high failure rate at the same gas conditions. Spoke elements tended to bow out resulting in deformed exit configurations. Increasing material thickness to resist deformation or failure resulted in severe blockage of secondary flow and an increase in thrust loss due to base drag.

A parametric study was conducted with several spoke nozzles where the number of spokes was 12, 24, or 36. Area ratio varied from 2 to 6. A slight decrease in maximum PNL suppression occurred as area ratio increased from 2 to 6 with the 24-spoke configuration. A 4- to 6-PNdB increase in maximum noise suppression was noted as the number of spokes was increased from 12 to 36. Figures 23, 24, and 25 summarize the results of the spoke parametric study. Nozzle deformation and ground reflection interference affect the accuracy of these results.

A 36-spoke, area-ratio-2.06 nozzle designated as HM-AP-45 was tested at the HNTF where free-field acoustic data could be measured under carefully controlled gas conditions. The results of these tests were reported in references 34 and 35. A large-scale 36-spoke nozzle was tested at Boardman, Oregon, on the J93 turbojet engine. There was good correspondence between model- and full-scale nozzle acoustic data. Noise characteristics showed agreement within 2 dB or 2 PNdB (see figs. 26 and 27). Full-scale test results are given in reference 11.

Multitube suppressor nozzle parametric studies tended to yield higher PNL suppression values with less thrust loss as compared to spoke-type nozzles. Hexagonal multitube arrays with 37, 126, and 330 tubes were tested. Area ratios varied from 2.8 to 8.0. Suppression as

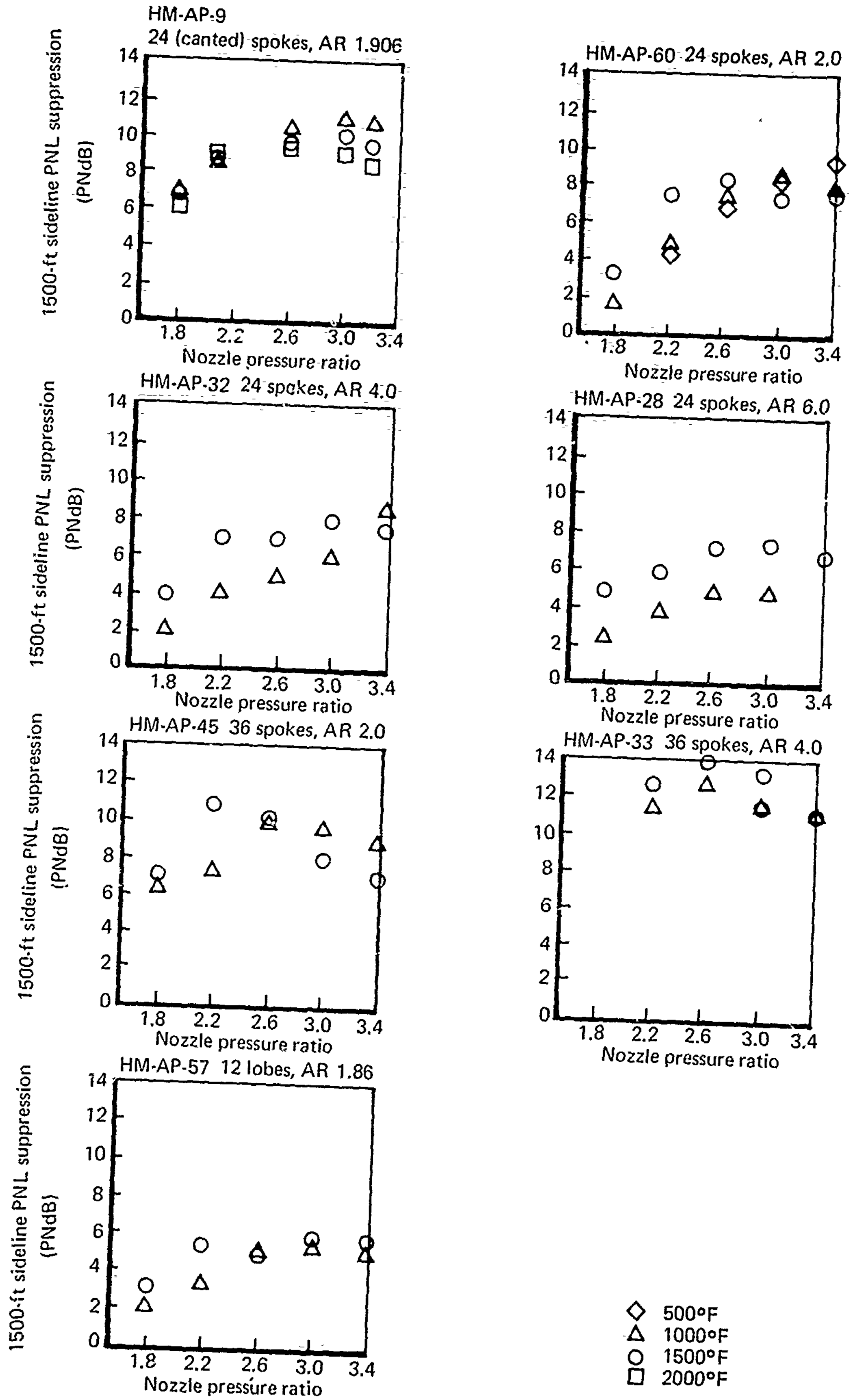


FIGURE 23.—VARIATION IN PNL SUPPRESSION WITH PRESSURE RATIO

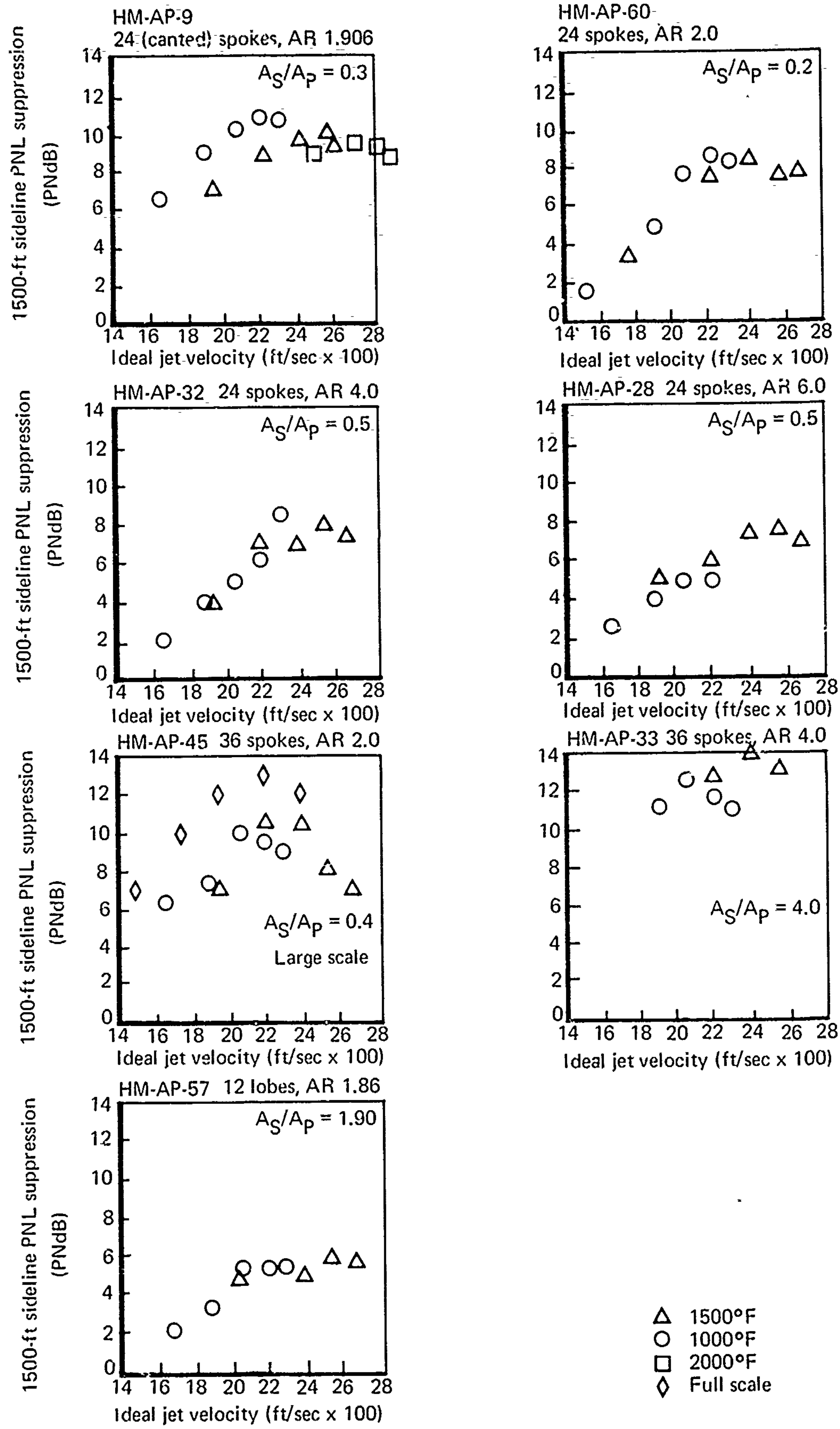


FIGURE 24.—VARIATION IN PNL SUPPRESSION WITH JET VELOCITY

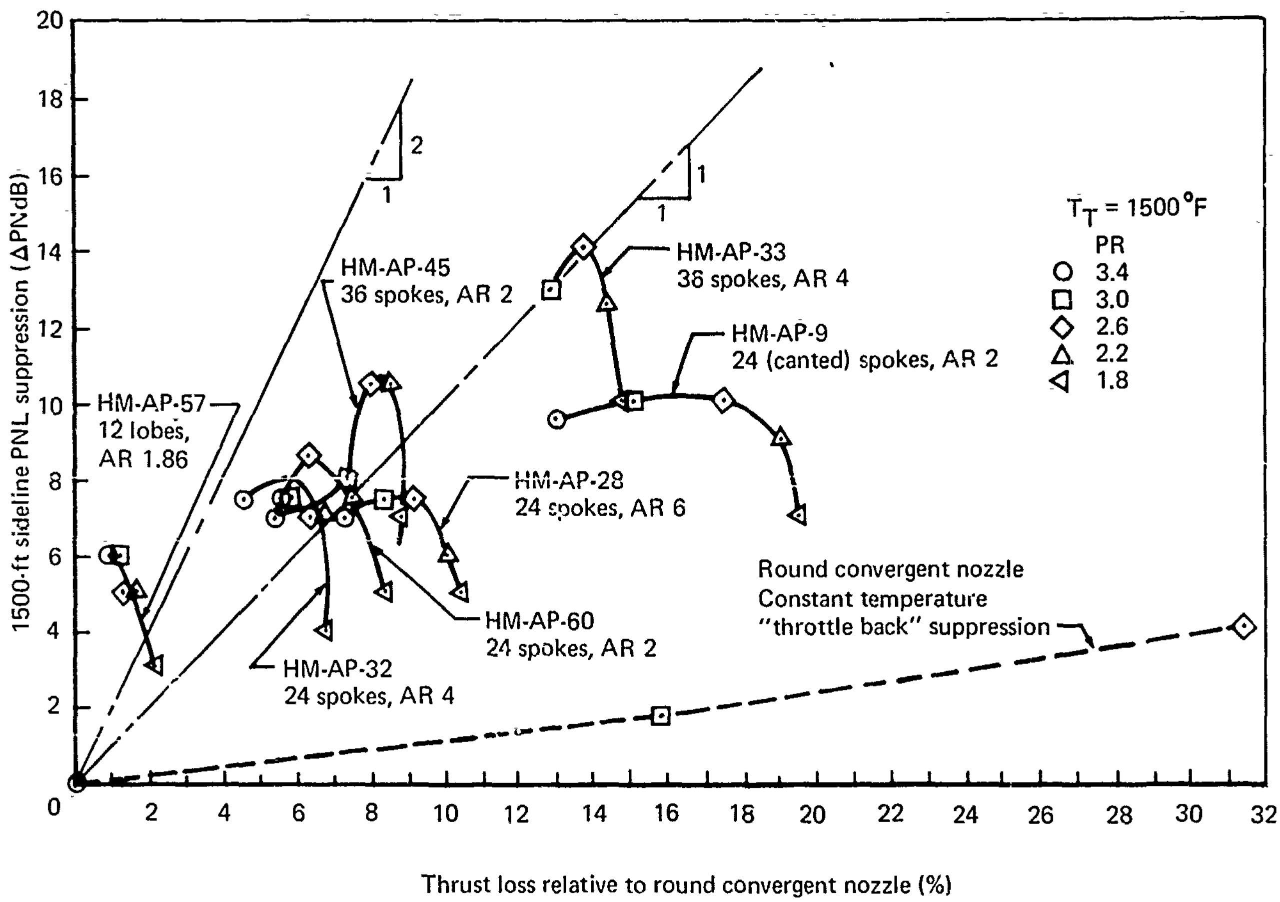


FIGURE 25.—SUMMARY OF 1500-FT SIDELINE PNL SUPPRESSION AND THRUST LOSS FOR MULTISPOKE NOZZLES

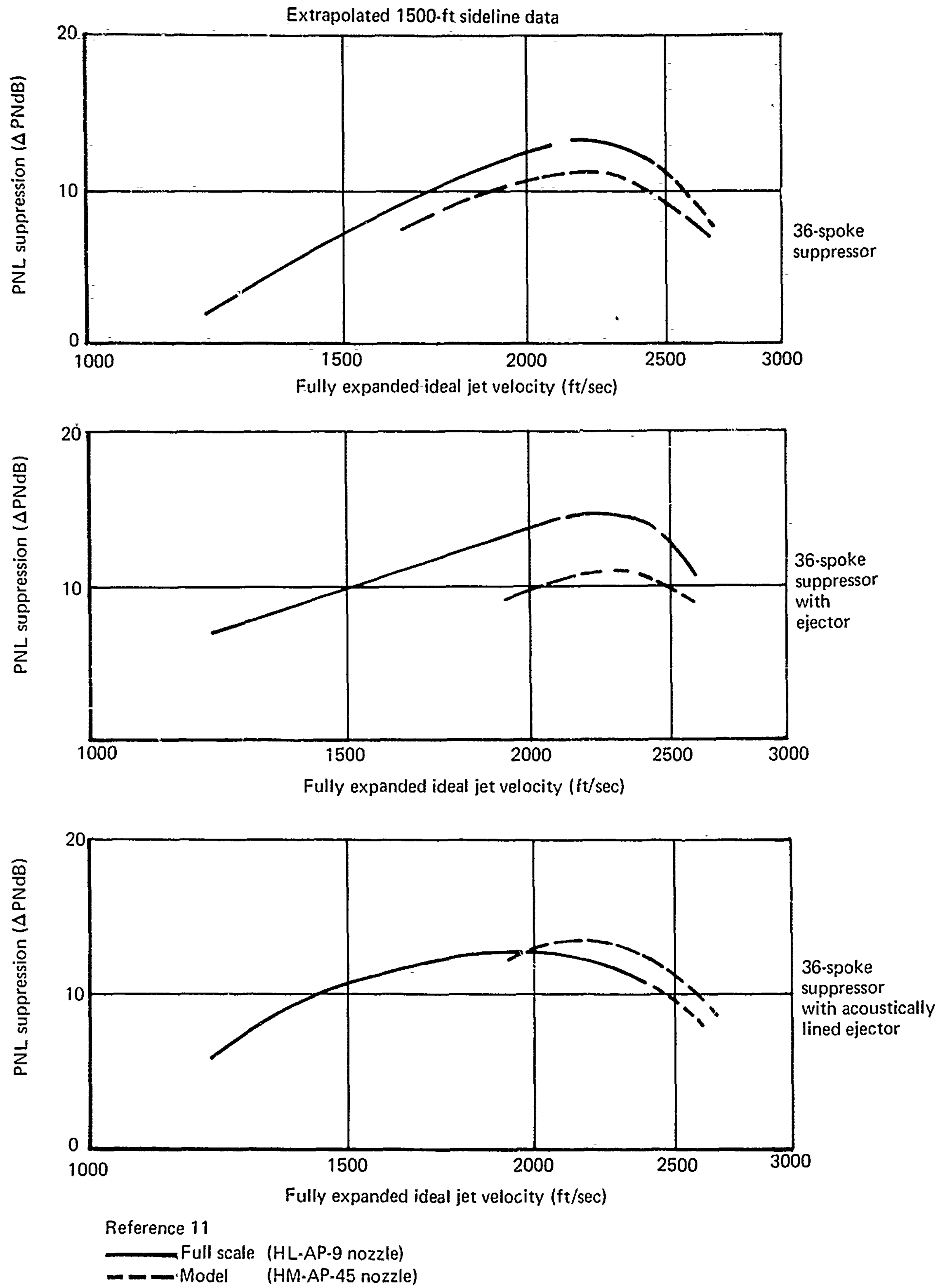


FIGURE 26.—COMPARISON OF FULL-SCALE AND MODEL PNL SUPPRESSION

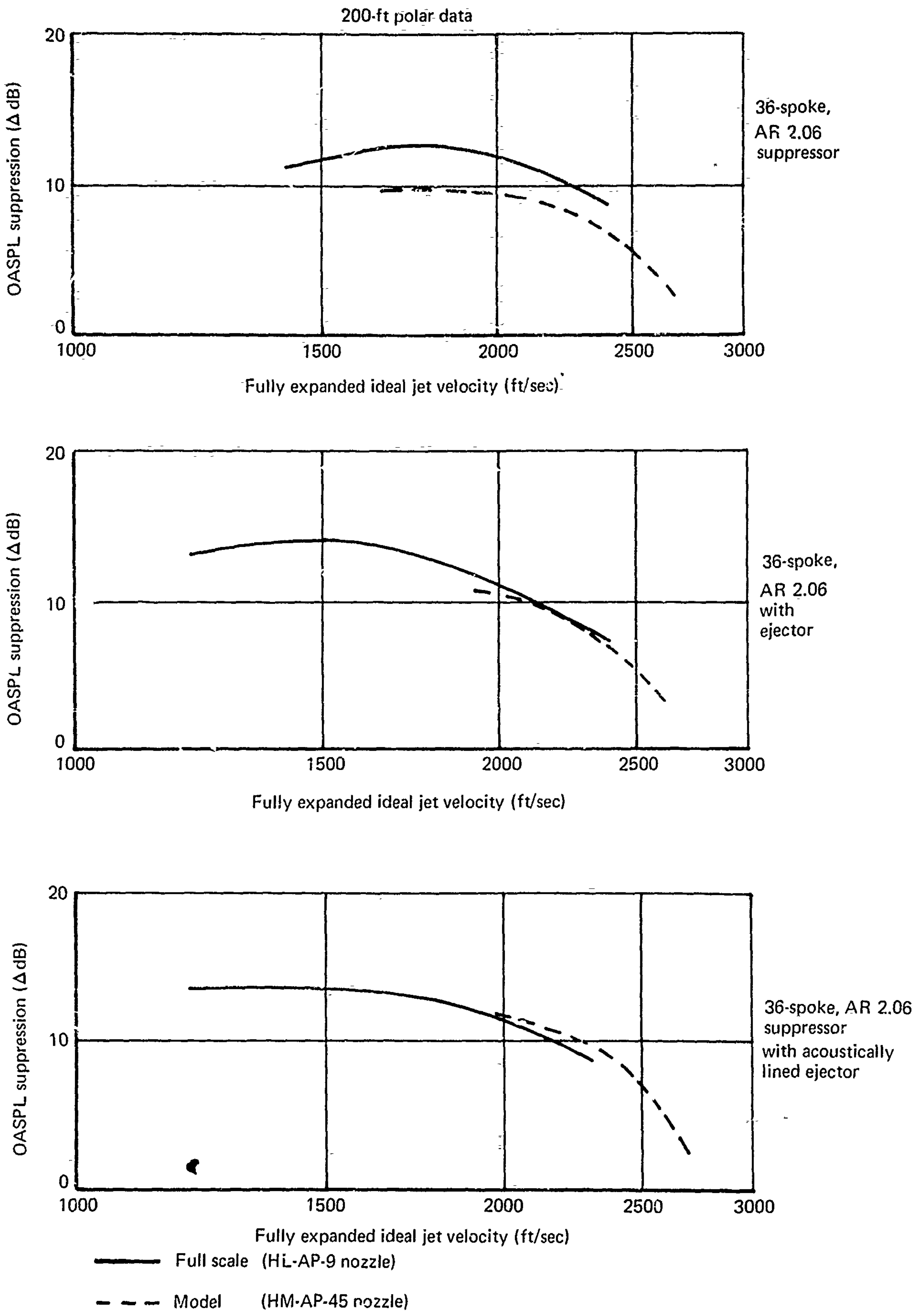


FIGURE 27.—COMPARISON OF FULL-SCALE AND MODEL OASPL SUPPRESSION

a function of jet velocity (ideal) is shown in figure 28. The highest suppression values (17 PNdB) were attained by 37-tube configurations that had 12-spoke-type ends on each tube. The 12-spoke ends resulted in 7% to 11% more thrust loss than round convergent ends.

Figure 29 shows the effect of PNL suppression on thrust loss characteristics for the 126-tube, area ratio-2.8 nozzle for various tube lengths. There is not much change evident in noise suppression values as tube lengths are varied from 0 to 56 in. (full-scale equivalent dimensions); however, thrust loss is significantly affected (see pages D277–D283). The multijet configuration primarily determines the noise characteristics of a suppressor nozzle without much dependence on thrust loss due to base drag shown.

Appendix C includes the PNL suppression values (PNdB) as a function of thrust loss (percent) for most of the eighth-scale suppressor nozzles tested in the SST high noise-suppression program. The range of gas conditions shown are T_T = 500°, 1000°, and 1500° F with PR = 1.8, 2.2, 2.6, 3.0, and 3.4. The 126-tube nozzle series was tested extensively over the full range of test conditions. Many of the nozzles were tested briefly only near gas conditions representing the GE4/J5P maximum dry-engine power setting.

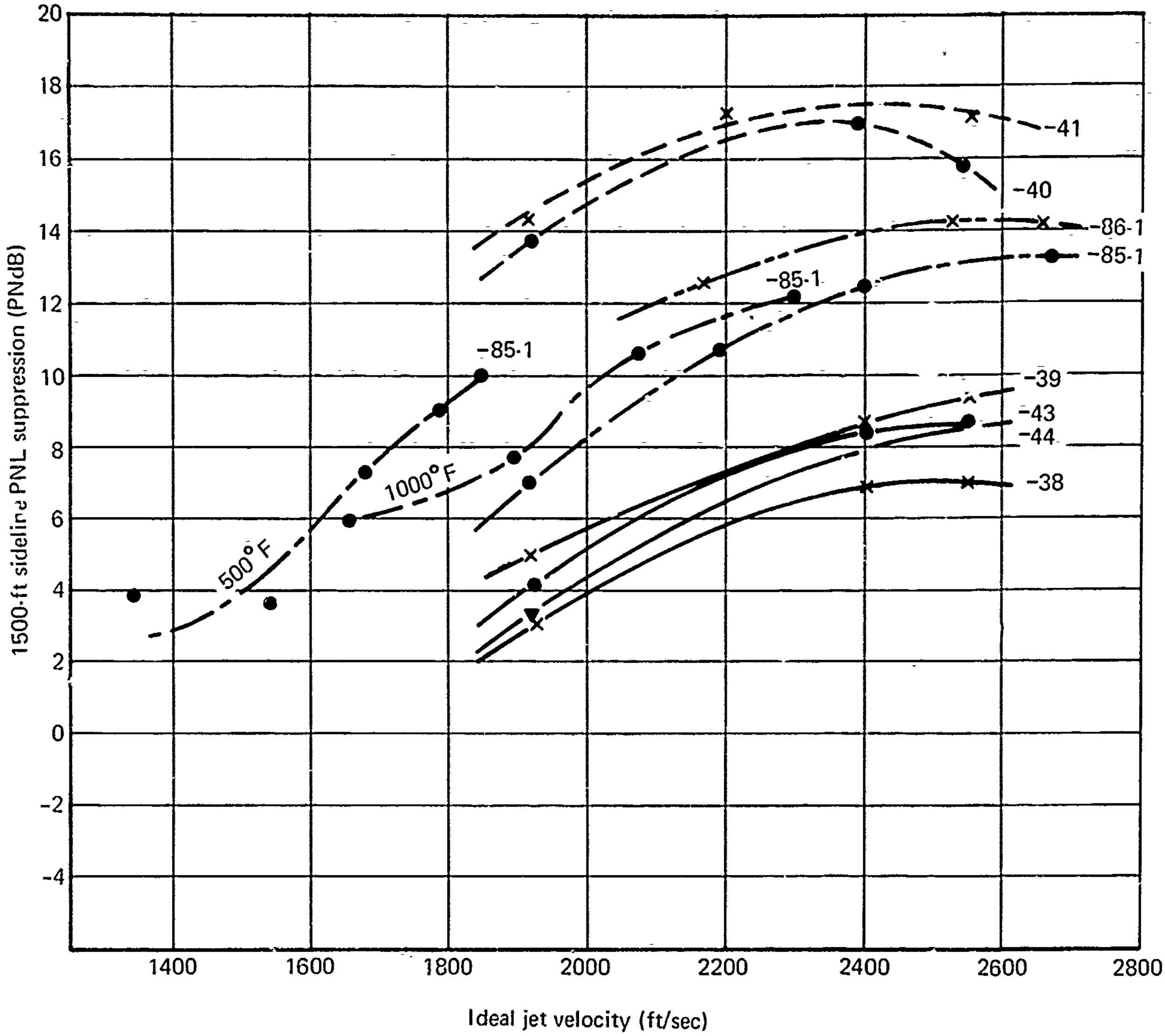
Several model-scale design suppressor nozzles were tested during the noise program. These nozzles were expected to provide between 12 and 20 PNdB sideline suppression at takeoff power settings with no more than 10% thrust loss. The length of the nozzle elements had to be kept short so that the suppressor nozzle could be stowed in the engine nacelle or ejector during cruise flight.

Figure 30 shows the relative noise-suppression and thrust-loss characteristics of the design nozzles tested. Installation of an ejector with an acoustically absorbent lining would improve these noise suppression values by at least 1 or 2 PNdB above those shown. The initial design concept was the HM-AP-6 nozzle, and the final concept was the NSC-119B nozzle. Techniques were developed during the SST jet noise suppression program to improve nozzle performance by reducing base drag without sacrificing noise suppression. The noise-suppression characteristics of low-area-ratio nozzles at high pressure ratios was improved upon. The NSC-119B nozzle represents an applicable design nozzle for a GE4-type turbojet engine (see ref. 28).

A compendium of model-scale suppressor nozzles tested during the 12- to 20-PNdB noise-suppression program appears in appendix D. This compendium includes a description of the nozzles, acoustic results, and propulsion performance results.

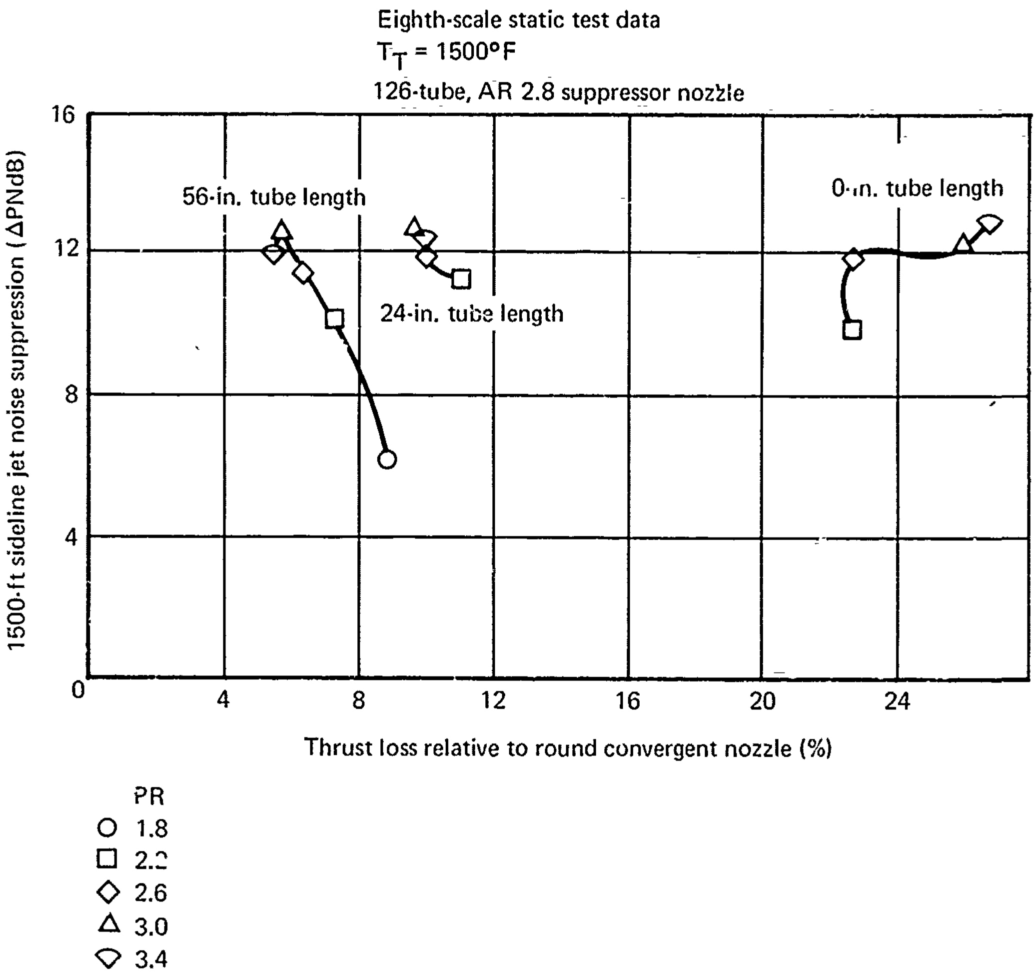
3.2.1.3 Normalization of Jet Noise Data

The SAE procedure for estimating jet noise levels (ref. 14) from a simple jet nozzle uses a normalization procedure to express overall sound pressure level as a function of fully expanded relative jet velocity. The SAE description of jet noise characteristics is limited to the overall sound pressure level (OASPL) at 45° relative to the jet axis and presented at the 200-ft sideline. Jet noise nominally peaks at 45° for jet engines operating without afterburner (e.g., gas temperature range of 800° to 1300°F).



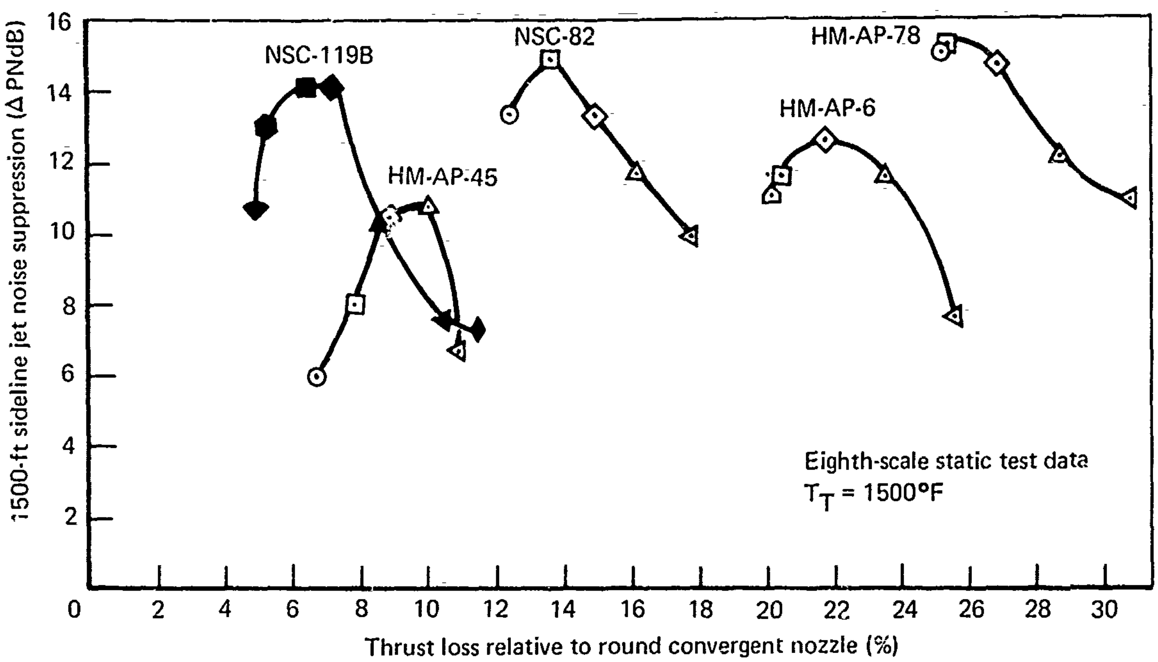
T_T = 1500°F except as noted	HM-AP-38	37 tubes	AR 8.0
	HM-AP-39	37 tubes	AR 4.0
	HM-AP-40	37 tubes with 12 spoke ends	AR 3.33
	HM-AP-41	37 tubes with 12 spoke ends	AR 4.0
	HM-AP-43	37 tubes	AR 3.33
	HM-AP-44	37 tubes	AR 5.2
	HM-AP-85-1	126 tubes	AR 3.33
	HM-AP-86-1	330 tubes	AR 4.0

FIGURE 28.--EFFECT OF JET VELOCITY ON HEXAGONAL MULTITUBE NOZZLE ARRAY SUPPRESSION



Note: Tube lengths are given in terms of full-scale dimensions; model-scale linear dimensions were adjusted by a factor of 1:8.

FIGURE 29.—SUPPRESSION/PERFORMANCE RELATIONSHIPS AS A FUNCTION OF TUBE LENGTH



Note: Suppression and thrust loss values are for nozzles with no ejector installed.

PR		
◊ = 1.6	HM-AP-6	Six lobe/multislot, AR 8.28
◁ = 1.8	HM-AP-78	16 spokes/208 tubes, AR 3.1
△ = 2.2	HM-AP-45	36 spokes, AR 2.06
◇ = 2.6	NSC-82	97 tubes, AR 2.85
□ = 3.0	NSC-119B	61 tubes, AR 2.9
⌂ = 3.2		
○ = 3.4		
⬡ = 3.6		
▽ = 4.0		

FIGURE 30.—SUPPRESSION/PERFORMANCE RELATIONSHIPS FOR DESIGN JET NOISE SUPPRESSOR NOZZLES

The SAE normalization procedure is based on a dimensional analysis of the original Lighthill equation

$$\text{Acoustic power} = \frac{K\rho^2 AV^8}{\rho_o a_o^5}$$

Jet noise data taken under relatively constant atmospheric conditions can be assumed to have a constant ambient air density (ρ_o) and speed of sound (a_o); therefore, for a simple subsonic jet, the above equation becomes

$$\text{Acoustic power} = K' \rho^2 AV^8$$

Assuming that the sound pressure level (SPL) at the angle where peak noise radiation occurs is proportional to the total acoustic power radiated, the variables as a function of jet velocity can be expressed as

$$\text{SPL} - 10 \log \rho^2 A = 10 \log f(V)$$

The velocity exponent is approximately 9 for subsonic jets in the direction of peak radiation (ref. 14).

Recent research has indicated that the velocity exponent may be different at the very low jet velocities (below 800 fps). Also, the gas density exponent may be less than 2 at these lower velocities. At jet velocities approaching 4000 fps, the velocity exponent has decreased to 3, see figure 31 (from ref. 14). This relationship is a valuable aid in predicting jet noise levels and as a check on baseline acoustic noise data acquired at the test facility.

Multispoke nozzle acoustic test data tend to "normalize" well with jet velocity by subtracting $\rho^2 A$ from the sound pressure level. Figure 32 is an example of normalized acoustic data from tests of the HM-AP-45 suppressor nozzle (36 spokes, area ratio 2.06). Multitube nozzle acoustic data do not normalize by subtracting $\rho^2 A$, as evidenced by the stratification of data for different total temperatures shown in figure 33 for the HM-AP-85-2 (126 tubes, area ratio 5.2) test data.

The original Lighthill equation from which the normalizing parameter $\rho^2 A$ was derived was based on early subsonic flow theory. Ffowcs-Williams in 1963 (ref. 36) suggested that radiated acoustic noise from a supersonic jet was proportional to

$$\frac{[1/2(\rho+\rho_o)]^2}{a_o^5 \rho_o} \frac{D^2}{X^2} V_R^7 V (1-M \cos \theta)^{-5} (1+N \cos \theta)^{-1}$$

where

D = jet diameter

X = distance from jet in far field

Jet noise = maximum passby OASPL at 200 ft off-axis normalized for ρ = 1 lb/ft^3, A = 1 ft^2

Reference 14

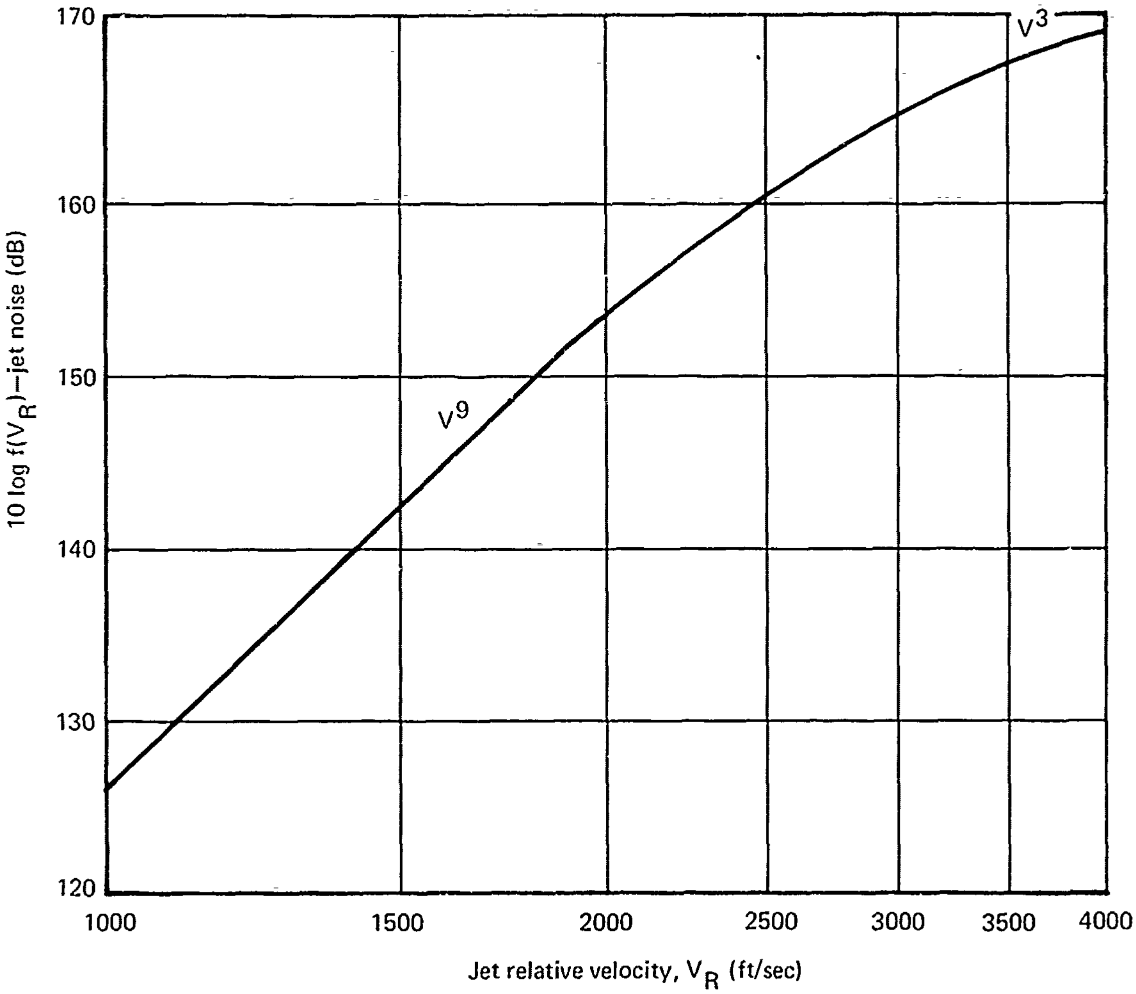


FIGURE 31.—EFFECT OF JET RELATIVE VELOCITY ON NORMALIZED JET NOISE FOR A SIMPLE JET

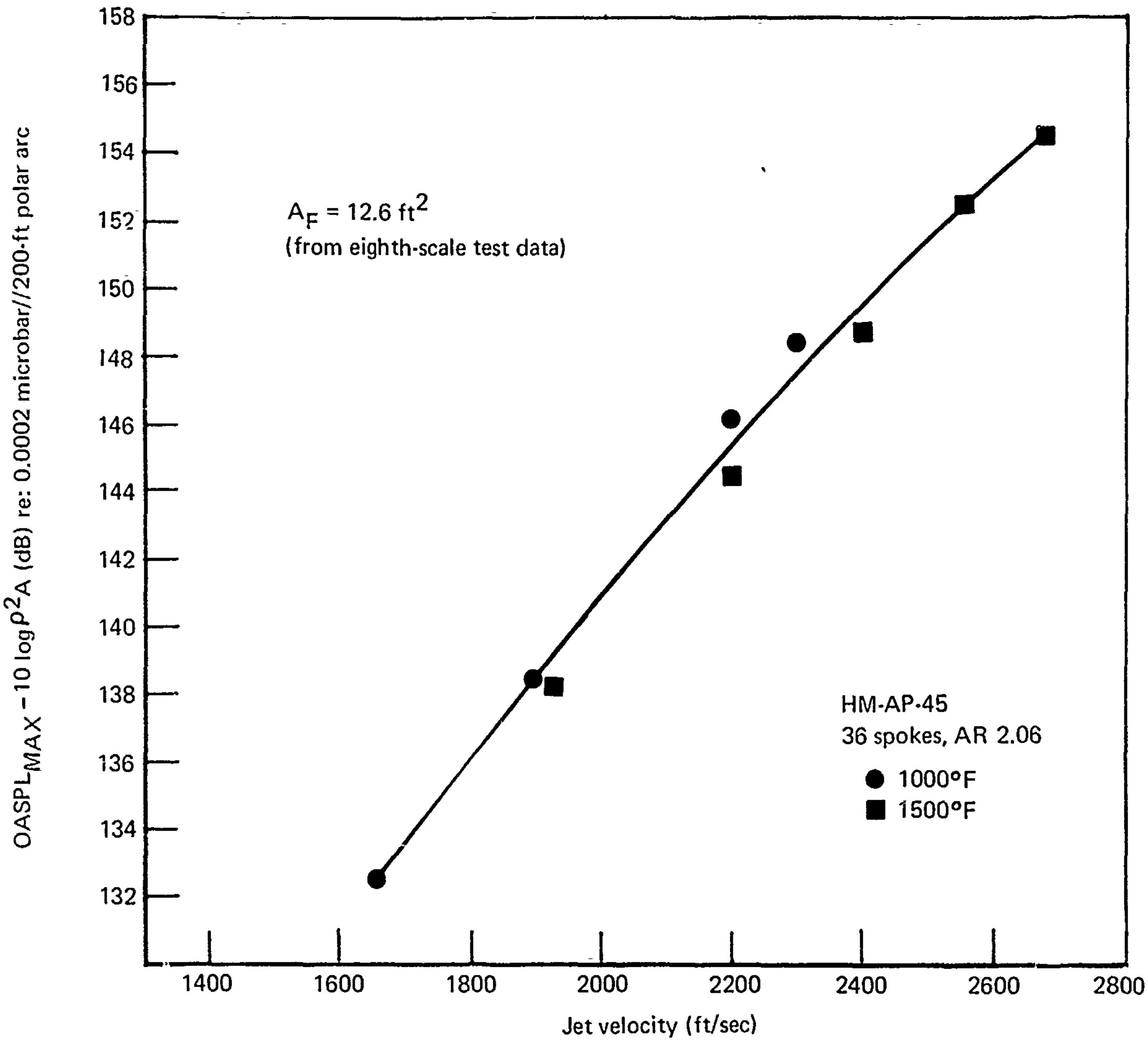


FIGURE 32.—NORMALIZED JET NOISE LEVELS FOR A 36-SPOKE, AREA RATIO-2.06 NOZZLE

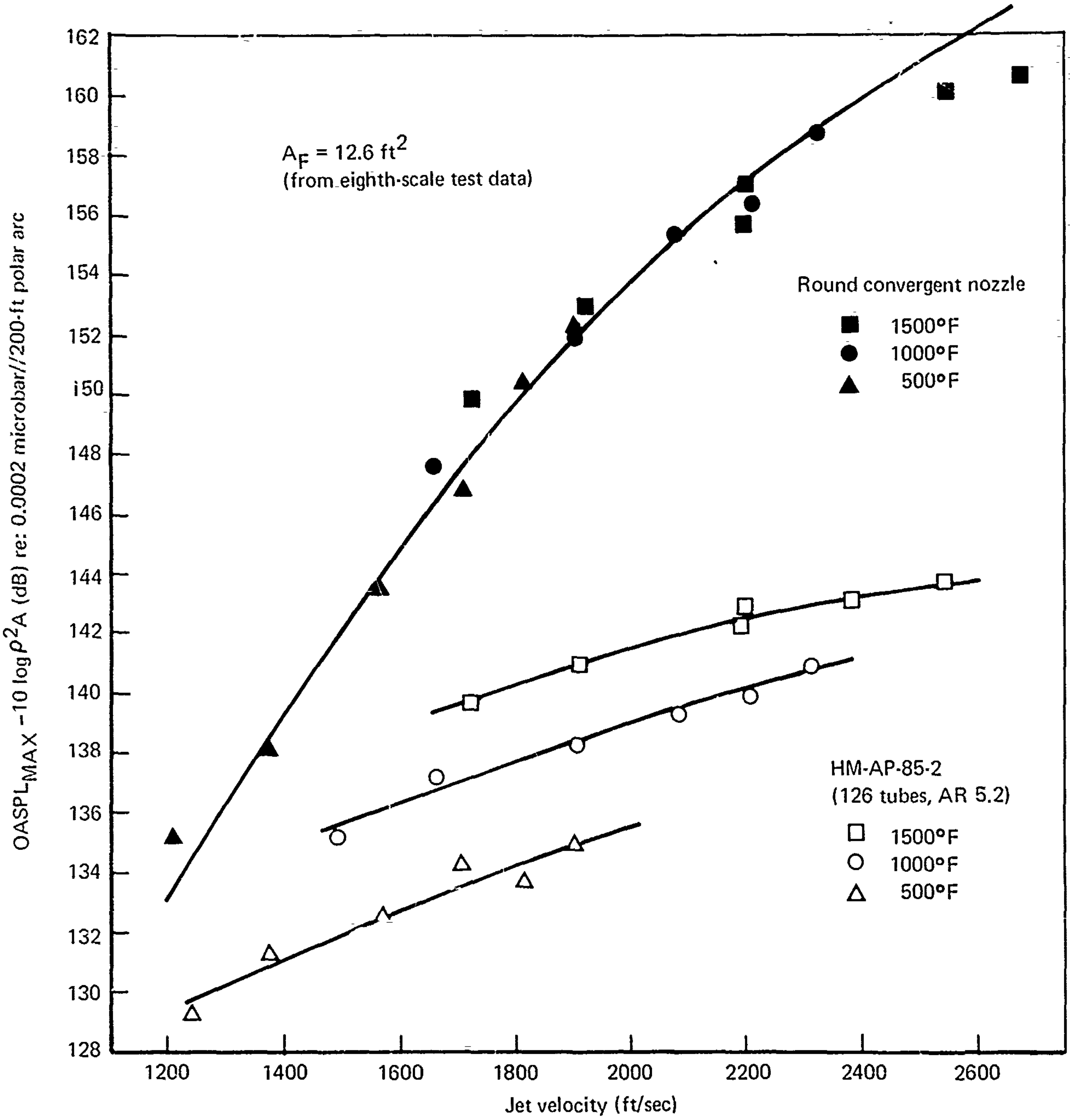


FIGURE 33.—SPL NORMALIZED BY 10 LOG ρ^2A FOR A 126-TUBE, AREA RATIO-5.2 NOZZLE AND A ROUND CONVERGENT NOZZLE

V_R = jet exhaust speed relative to atmosphere

V = jet exhaust speed relative to aircraft

M = Mach number of eddy convection velocity

N = Mach number of aircraft

θ = angle to jet axis

For static tests, the sound intensity will be proportional to $(\rho + \rho_0)^2 AV^n$. When 10 log $(\rho + \rho_0)^2 A$ is subtracted from sound pressure levels in dB obtained from tests of a round convergent nozzle and plotted against jet velocity, a stratification of data occurs at different jet total temperatures.

For static jet noise testing with near-constant atmospheric conditions and removing the directionality factors in the equation, radiated acoustic power will be very nearly proportional to $K(\rho + \rho_0)^2 AV^n$ under conditions of supersonic flow. A normalizing parameter of $(\rho + \rho_0)^2 A$ is indicated here.

This normalizing parameter was applied to sound pressure levels in dB measured from a round convergent nozzle by subtracting 10 log $(\rho + \rho_0)^2 A$ and plotting the results against jet velocity. A stratification of data thus normalized occurred as a function of temperature.

When the $(\rho + \rho_0)^2 A$ normalizing parameter was applied to multitube nozzle acoustic data, a good correspondence of data was apparent when plotted against jet velocity (ideal), provided the noise spectra were dominated by high-frequency mixing noise. Figure 34 is an example of multitube nozzle noise levels normalized by subtracting 10 log $(\rho + \rho_0)^2 A$. The 126-tube, area ratio-5.2, normalized overall sound pressure levels show good agreement, while the round convergent nozzle data stratify with temperature.

The $(\rho + \rho_0)^2 A$ normalizing parameter was applied to the acoustic data from the following multitube nozzle tests:

Tubes	Area ratio
37	3.33
61	2.9
97	2.85
126	2.8
126	3.33
126	5.2
330	4.0

This particular study was not completed and the range of application was not determined. The $(\rho + \rho_0)^2 A$ normalizing parameter applies well to multitube nozzle acoustic data under supersonic primary flow conditions, provided jet-coalescence-generated noise does not dominate the spectrum. Very few acoustic data were acquired in the subsonic primary flow region during the SST program, and it has not been determined how well $(\rho + \rho_0)^2 A$ applies for this case.

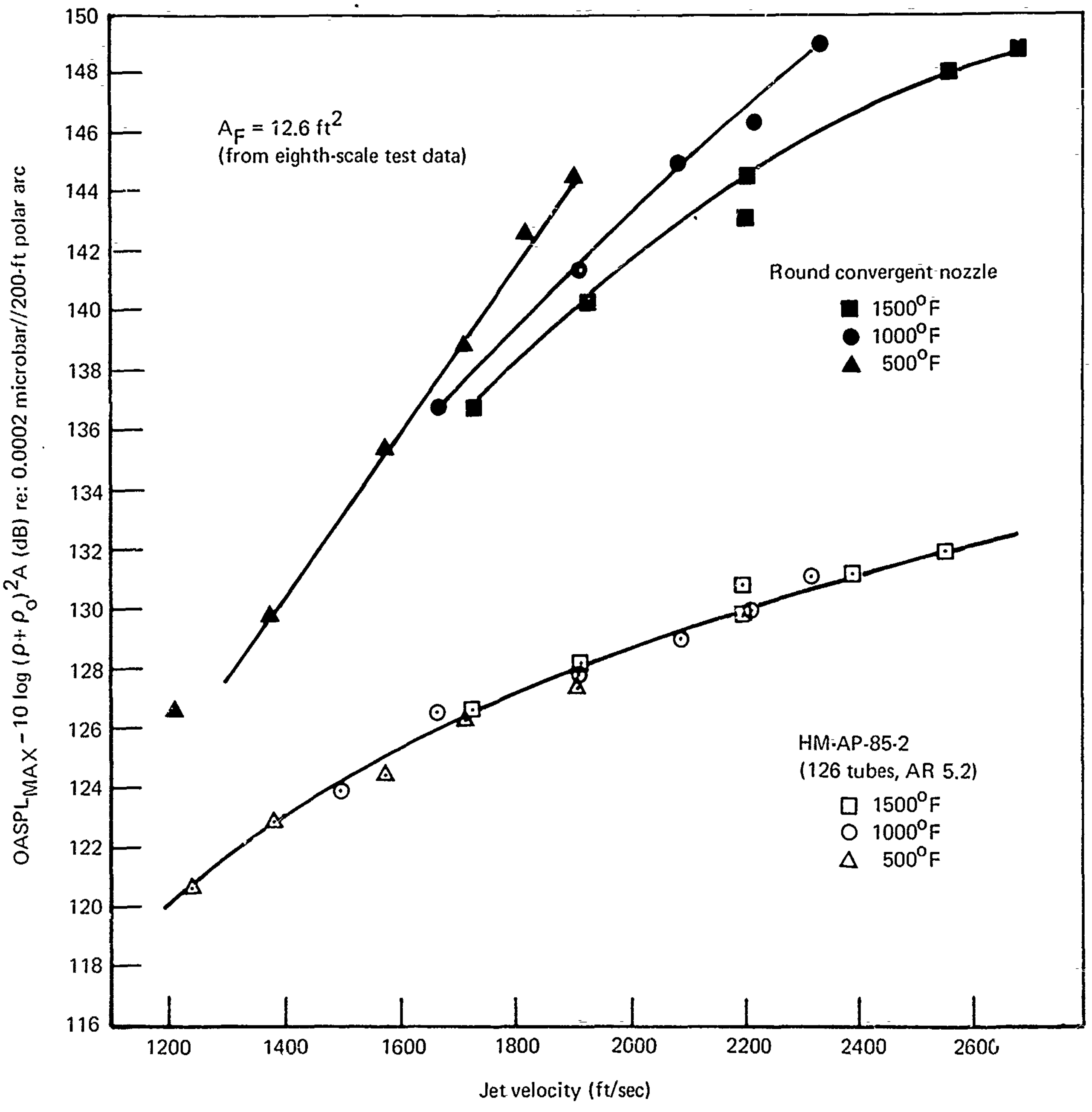


FIGURE 34.—SPL NORMALIZED BY 10 LOG ($\rho + \rho_o)^2$A FOR A 126-TUBE, AREA RATIO-5.2 NOZZLE AND A ROUND CONVERGENT NOZZLE

Figure 35 shows 37-tube, area ratio-3.33 suppressor nozzle average OASPL normalized by 10 log ρ^2A and 10 log $(\rho + \rho_0)^2$A, respectively. Neither method provides good correspondence of sound pressure levels over the complete range of gas conditions tested. For this nozzle the acoustic data acquired at pressure ratios greater than 2.6 are normalized by -10 log ρ^2A. and data acquired at pressure ratios less than 2.6 are normalized by -10 log $(\rho + \rho_0)^2$A. Good correspondence of test data occurs as shown in figure 36. The jet coalescence noise dominates over the jet mixing noise at pressure ratios greater than 2.6 for this particular multitube nozzle, and the coalesced jet has characteristics similar to a simple jet where ρ^2A applies best as the normalizing factor. When jet mixing noise dominates, $(\rho + \rho_0)^2$A is the better normalizing term.

Changes in overall sound pressure levels (dB) have been observed to change perceived noise levels (PNdB) by approximately the same amount. Therefore, perceived noise levels may often be normalized by the same factors even though a tenuous relationship exists between dB and PNdB.

SAE predicted noise levels at the 1500-ft sideline for a range of engine conditions where T_T = 500°, 1000°, 1500°, 2000°, 2500°, and 3000° F and PR = 1.8, 2.2, 2.6, 3.0, and 3.4 were normalized by subtracting 10 log ρ^2A. The normalized PNL values as a function of velocity (fig. 37) showed close correspondence, being within ±0.5 PNdB of the mean (ref. 37). Normalized PNL values are useful in making quick estimates of jet noise levels in engine cycle studies and may provide a relationship to account for relative velocity effects.

Figure 38 shows examples of normalized PNL values for a 37-tube, area ratio-3.33, suppressor nozzle. Estimates of suppressor nozzle noise levels can be made easily from normalized PNL relationships for engine cycle studies that fall within the range of gas conditions shown. Noise predictions from normalized PNL relationships have provided results that are within ±0.5 PNdB of predictions obtained by conventional methods. This degree of accuracy is well within the accuracy of the original measured data.

It should not be construed that ρ^2A and $(\rho + \rho_0)^2$A are the final answers to jet noise normalization. As knowledge about jet noise generation processes improves, normalization terms will become more complete in their scope.

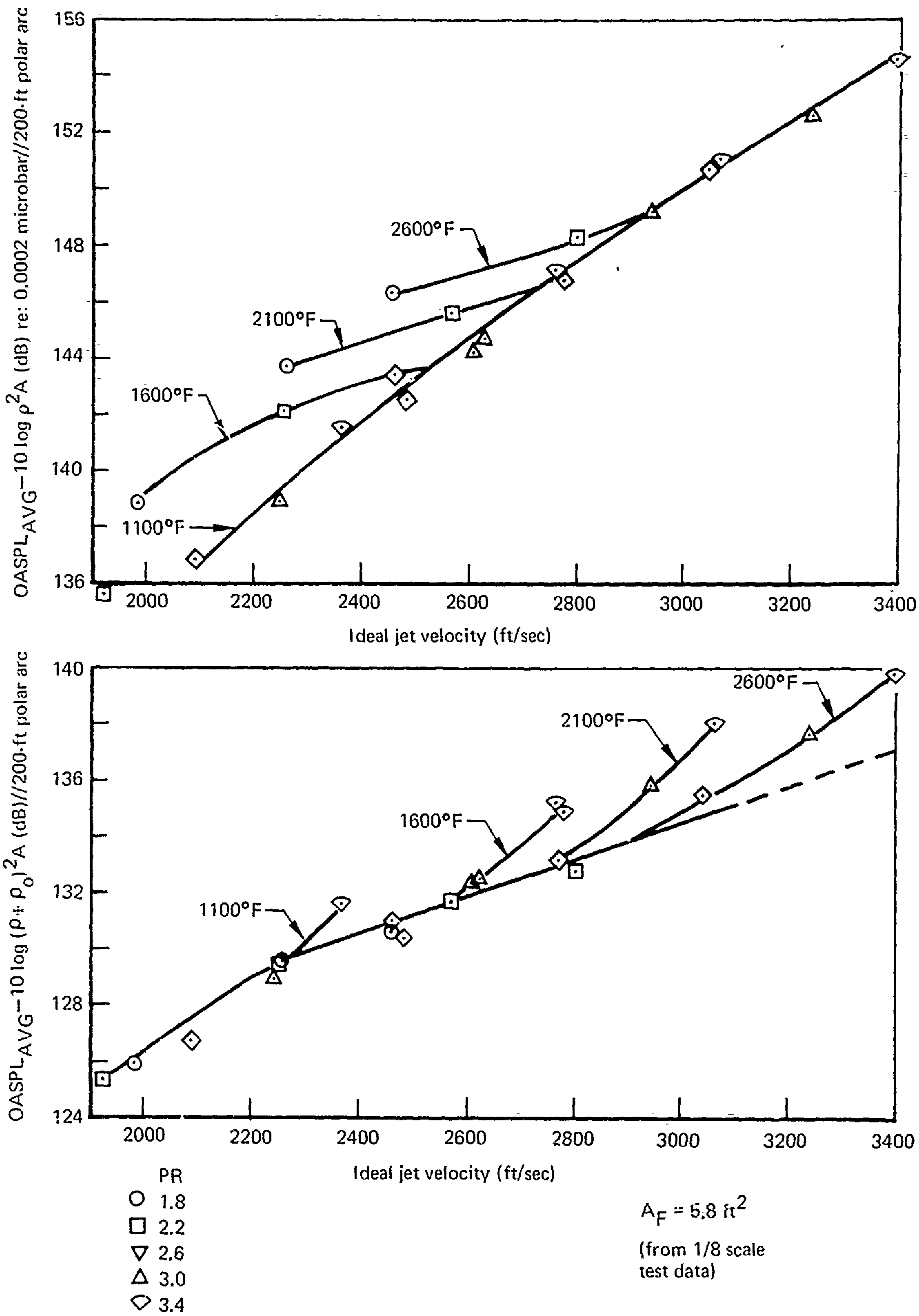


FIGURE 35.—NORMALIZED JET NOISE LEVELS FOR A 37-TUBE, AREA RATIO-3.33 MULTITUBE NOZZLE

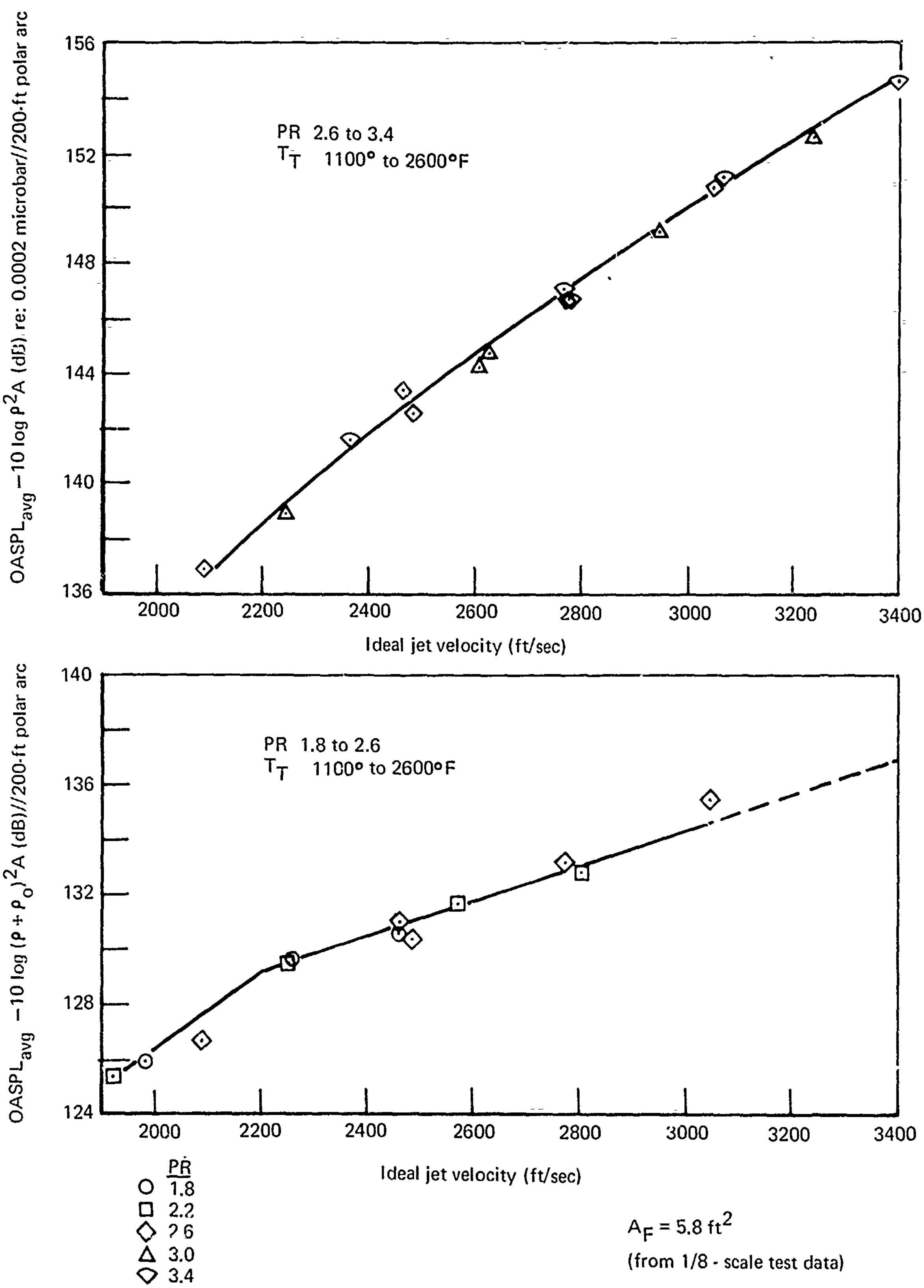


FIGURE 36.—NORMALIZED JET NOISE LEVELS FOR A 37-TUBE, AREA RATIO-3.33 MULTITUBE NOZZLE WITH LIMITED PRESSURE RATIO CONDITIONS

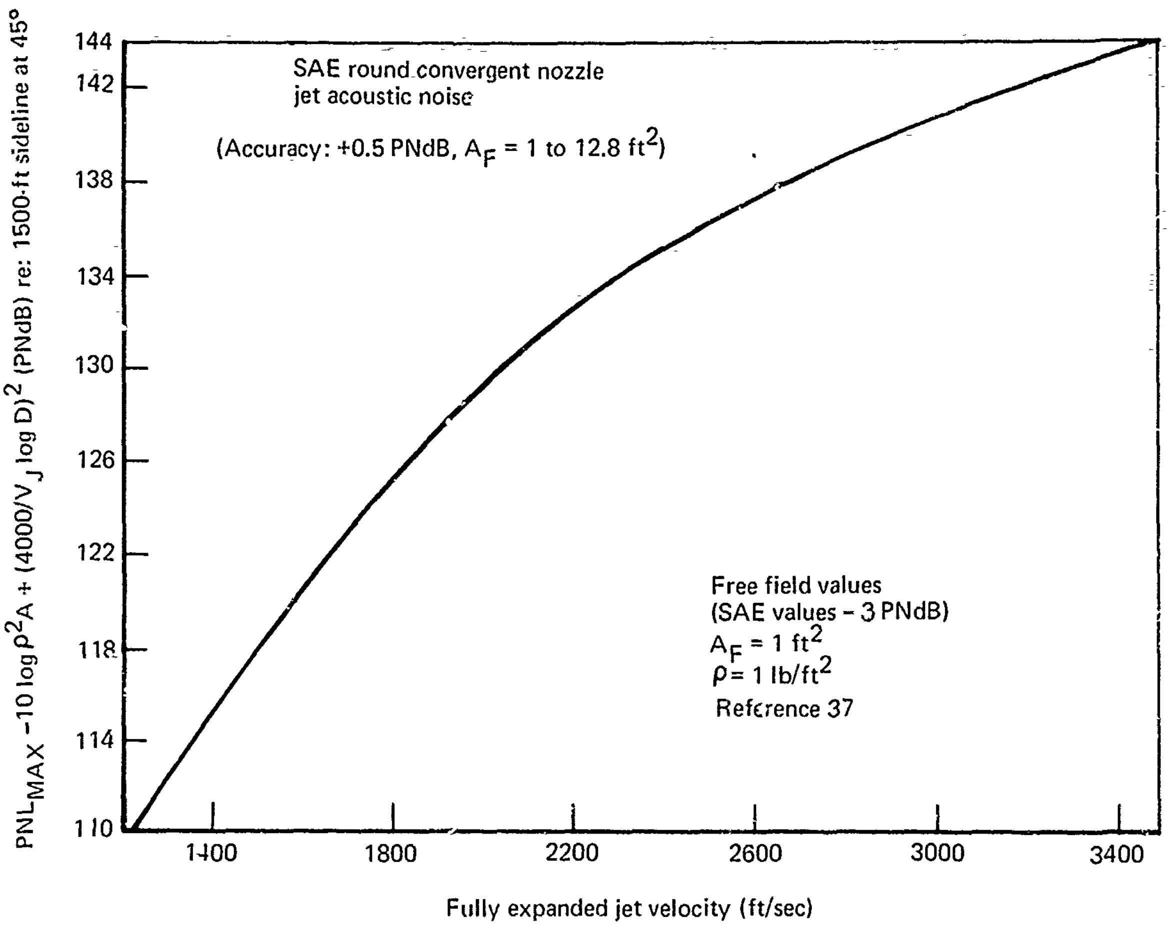
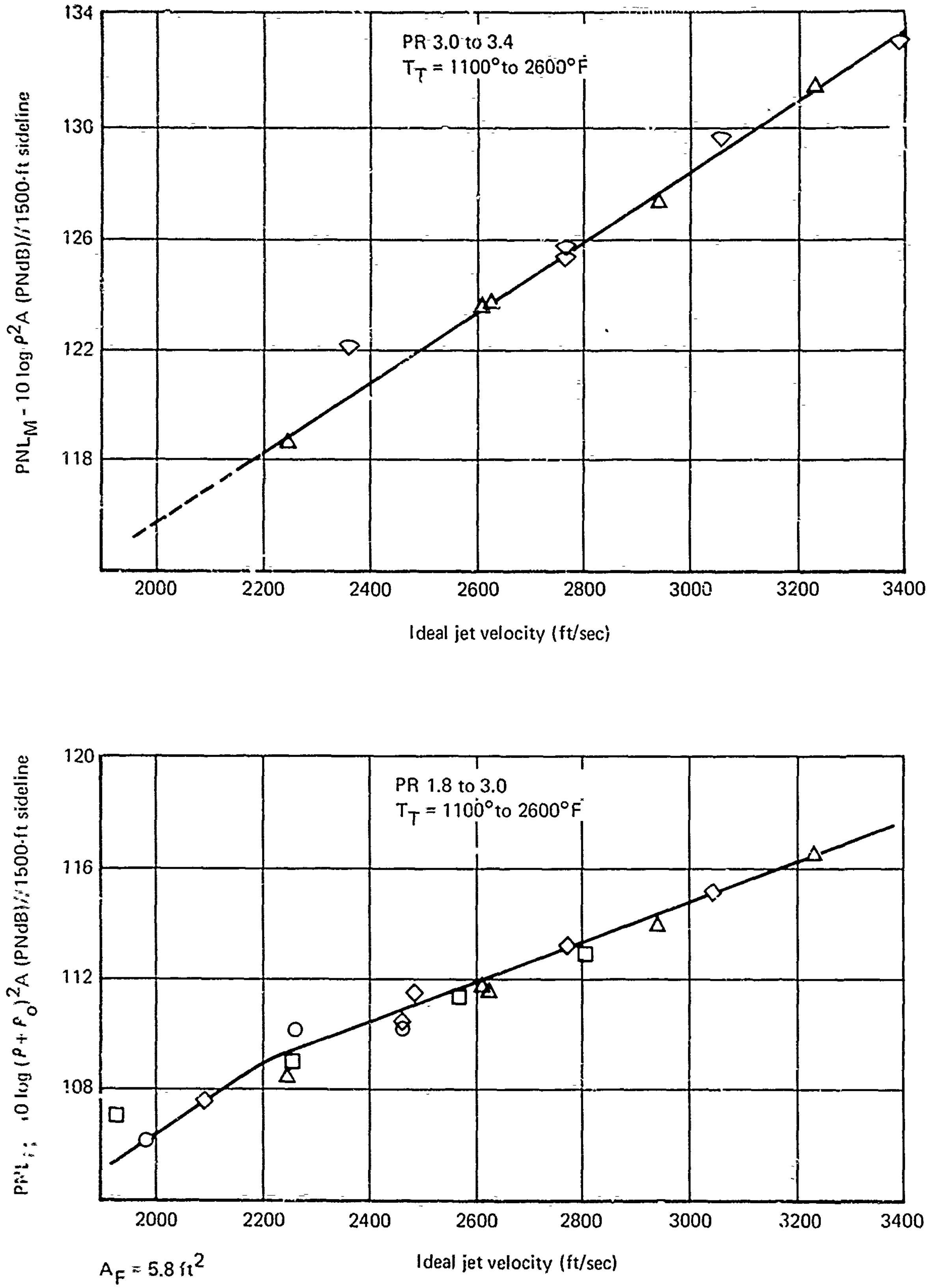


FIGURE 37.—NORMALIZED 1500-FT SIDELINE PNL VALUES FOR A ROUND CONVERGENT NOZZLE



A_F = 5.8 ft^2
(from 1/8-scale test data)

FIGURE 38.—NORMALIZED PERCEIVED NOISE LEVELS FOR A 37-TUBE, AREA-RATIO-3.33 MULTITUBE NOZZLE

4.0 CONCLUSIONS

Model-scale nozzle jet noise characteristics appear to agree with full-scale nozzle test results. Control of ground reflection interference is especially important to obtain free-field acoustic data. In this way, acoustic data acquired at one facility are more likely to compare with acoustic data from another facility.

Model-scale nozzle testing provides acoustic and propulsion data over a wide range of gas conditions, economically. It is advisable to test suppressor nozzles at ambient total temperature to acquire accurate coefficients of discharge. This information, together with accurate thrust values during acoustic testing at hot-flow primary gas conditions, is imperative in checking indicated total-temperature data. A mean value of total temperature is very difficult to obtain by direct measurement, yet jet velocity (and noise) is very sensitive to gas temperature.

Multitube nozzle configurations have shown greatest potential for attaining high jet noise suppression with low thrust loss under supersonic flow conditions. Multitube nozzle designs have greater structural integrity under conditions of high temperature and high engine pressure ratios.

The radiated acoustic spectra of multielement nozzles contain high-frequency energy attributed to noise generated by the elemental jet mixing region. Low-frequency acoustic energy is attributed to shear as the elemental jets coalesce and to the fully coalesced jet. Increasing the spacing between elemental jets causes a reduction in low-frequency noise levels. There appears to be an optimum spacing ratio between elemental jets to reduce high-frequency noise levels. Increases of pressure ratio tend to increase low-frequency noise with relatively little effect on high-frequency noise.

A hard-wall ejector surrounding the elemental jet mixing region has little effect on suppressor nozzle jet noise characteristics unless the ratio of ejector diameter to nozzle array diameter approaches unity. Suppression of 1 to 2 PNdB is possible with a tight-fitting hard-wall ejector.

Ejectors lined with fiberglass batting have provided 5 to 12 dB suppression of jet mixing noise in the high-frequency portion of the spectrum. It has not been determined how well model-scale ejector lining acoustic characteristics compare with full-scale performance.

Suppressor nozzles tend to reach maximum values (PNdB) of suppression at fully expanded jet velocities between 2100 and 2600 fps. At jet velocities of 1100 to 1600 fps, these same nozzles may exhibit no suppression value, although further study is needed in this range.

The noise characteristics of multielement suppressor nozzles are not significantly affected by element length. A change in element length does affect thrust coefficient by changing nozzle base static pressures (base drag).

The SAE method of predicting jet noise levels declines in accuracy when extraordinary engine conditions are involved. In engine-cycle studies involving supersonic or high-temperature flow conditions, it was prudent to verify predicted acoustic noise values with model-scale nozzle test data.

5.0 RECOMMENDATIONS

Radiated jet acoustic noise should be measured under far-field and free-field conditions so that noise spectra can be better interpreted and test results made more concise. The length of the jet over which the sound is generated should be determined, especially at supersonic flow conditions, to ensure that microphone locations are satisfactory for measuring the noise field with no parallax problems. Techniques for controlling ground reflection interference, especially in full-scale testing, need to be developed.

Investigations of ultrasonic sound propagation anomalies (e.g., air absorption loss and wind-induced turbulence) should be initiated to improve scaling relationships between model-scale and full-scale jet noise testing. It is desirable to express measured acoustic data in terms of standard-day conditions, and propagation loss values must be clearly defined.

Test facilities should be developed to measure jet noise and nozzle performance in the presence of forward velocity conditions. The methods for extrapolating static measured noise data to account for in-flight effects are not defined at this time. The relative velocity effect on noise generation is needed, especially for suppressor nozzle and ejector research. Improved temperature monitoring and stabilizing techniques are also required.

Measured acoustic data should be extrapolated from a predicated aircraft altitude of 1000 ft because propagation losses to the 2128-ft sideline are minimal at this altitude when using SAE extrapolation procedures. The actual propagation loss to the 2128-ft sideline needs to be determined by sound propagation studies under a wide range of meteorological conditions and locations. There is reason to believe that long-range propagation losses are ill defined at this time.

Noise levels in buildings (dwellings) should be considered when evaluating suppressor nozzle concepts. Currently, only out-of-doors annoyance levels are considered. Typical sound transmission loss values through building structure need to be used and indoor noise annoyance standards established.

A matrix of primary gas conditions is necessary in testing suppressor nozzle concepts for future engine developments. A wide range of engine conditions should be considered so that acoustic data can be interpolated conveniently for takeoff, cutback, and approach conditions as well as for engine-cycle studies.

Retest of some suppressor nozzle concepts is warranted, since current improvements in measurement techniques will provide better acoustic data. Many suppressor nozzles were tested over a very limited range of conditions, and retesting will fill gaps in the parametric studies already initiated.

Far-field acoustic data can only provide superficial answers to the noise-suppression problem. If the techniques of jet noise suppression are to progress, many methods have to be used to more completely define the multielement jet flow and noise generation processes and to clear up the suppositions currently espoused. Relations must be established evaluating the relative importance of changes in noise generation, redirection, or control of noise once generated, and attenuation of noise once radiated from the flow. These must be correlated with changes in nozzle geometry and fluid flow parameters. Techniques now exist to conduct such studies.

PRECEDING PAGE BLANK-NOT FILMED

REFERENCES

The coordination sheets referenced below are normally internal Boeing correspondence. However, copies of the particular ones listed may be obtained through the Commercial Airplane Library, The Boeing Company, Renton, Washington.

1. R. H. Sawhill, *The Effect of Ejector Design Parameter Changes on the Acoustic Performance of Ejector-Jet Nozzle Combinations*, T6-3488, The Boeing Company, November 1965.

2. H. D. Sowers, *Research on Jet Noise Suppressor Designs*, Report R65FPD196, Bureau of Naval Weapons, August 1965.

3. R. Lee et al., *Research Investigation of the Generation and Suppression of Jet Noise*, Bureau of Weapons Contract NOas 59-6160-C, General Electric Company, January 1961.

4. *SST Aircraft Engine Phase II—A Development Program*, Final Report 2397, vol. II, item 9, "Noise Reduction," Pratt and Whitney Aircraft, November 30, 1964.

5. J. E. Postlewaite, *Performance of Several Jet Wake Noise Suppressors*, D6-11237 TN, The Boeing Company.

6. J. V. O'Keefe and R. B. Tate, *SST Engine Noise Suppression Study Scale Model Tests*, T6A10341-1, The Boeing Company, September 1966.

7. J. Campbell and E. A. Wolff, *Scale-Model Jet Noise Suppression Program*, T6A11035-1, The Boeing Company, March 1968.

8. W. Klang, *Engine Noise Suppression Program—SST*, T6A10341-3, The Boeing Company, October 1966.

9. G. W. Bielak et al., *Large-Scale Jet Noise Suppression Tests—Acoustic and Performance Evaluation (Series 1)*. T6A11034-1, The Boeing Company, March 1968.

10. G. W. Bielak et al., *Large-Scale Jet Noise Suppression Tests—Acoustic and Performance Evaluation (Series 2)*, T6A11034-2, The Boeing Company, May 1968.

11. G. C. Teeter and J. R. Alberti, *Thirty-Six-Spoke Jet Noise Suppressor Acoustic and Performance Test Analysis*, D6A11501-1, The Boeing Company, March 1969.

12. D. A. Bateman, *Model Afterburning Engine for Acoustic Research*, D6-17870, The Boeing Company, July 1965.

13. D. R. Zable, *Description and Evaluation of a Thrust Rig—Acoustical Model Jet Test Facility/Annex D*, D6A11295-1 TN, The Boeing Company, July 1968.

14. AIR 876, "Jet Noise Prediction," Society of Automotive Engineers, Inc., July 10, 1965.

15. ARP 866, "Standard Values of Atmospheric Absorption as a Function of Temperature and Humidity for Use in Evaluating Aircraft Flyover Noise," Society of Automotive Engineers, Inc., August 31, 1964.

16. AIR 923, "Method for Calculating the Attenuation of Aircraft Ground-to-Ground Noise Propagation During Takeoff and Landing," Society of Automotive Engineers, Inc., August 15, 1966.

17. D. G. Dunn, *Airport and Community Noise Prediction for Aircraft Using Turbojet or Turbofan Engines With or Without Noise Suppressors*, D6A-11478-1 TN, The Boeing Company, revised June 5, 1969.

18. D. G. Dunn and J. V. O'Keefe, *Acoustic Far-Field Investigations*, T6A10493-3, The Boeing Company, April 1968.

19. Coordination Sheet 733-EDAS-10, "Engine Noise Suppression Program for SST—Progress Report," R. H. Sawhill, April 21, 1966.

19.1 F. G. Strout, *Multi-Spoke Suppressor Nozzle Characteristics—Volume 1—Parametric Thrust Performance*, D6A12118-1 (informal), The Boeing Company.

20. Coordination Sheet 733-EDAS-31, "Engine Noise Suppression Program—SST Progress Report 5 PNdB Program—PWA Suppression Studies," R. B. Tate and J. V. O'Keefe, June 24, 1966.

21. Coordination Sheet SST-AN-20-63, "Scale Model Jet Noise Suppression Program, Chute Longitudinal Position and Angle of Attack Studies Report," J. M. Campbell and J. V. O'Keefe, October 26, 1967.

22. Coordination Sheet SST-AN-20-122, "Angle-of-Attack Study Retest," J. M. Campbell, January 31, 1968.

23. Coordination Sheet 733-EDAS-60, "Status Report—J-75 Suppressor Test Program," R. B. Tate, September 9, 1966.

24. Coordination Sheet 733-EDAS-68, "Acoustic Data Analysis—J-75 Suppressor Tests," R. B. Tate and J. Zurcher, November 21, 1966.

25. R. D. Cuthbertson and J. V. O'Keefe, *Acoustic and Performance Evaluation of a B-2707 Jet Noise Suppressor (SST)*, T6A10493-2, The Boeing Company, August 1967.

25.1 L. L. House, *Test Data Report—Thrust Performance of Pure Annulus and Multi-Tube Annular Sound Suppression Convergent Nozzles*, T6A10814-1, The Boeing Company, November 1967.

26. Coordination Sheet SST-ANPD-187, "The Effect of Area Ratio on the Suppression Characteristics of a 126-Tube Nozzle," A. W. Elston, August 26, 1969.

27. Coordination Sheet G-8572-70-54, "A Cursory Study of Overall SPL Suppression Characteristics of Multitube Nozzle Jets," C. P. Wright, September 30, 1970.

28. H. Lu et al., *SST Technology Follow-On Program—Phase I, Evaluation of the NSC-119B Nozzle System Vol I Installed Modes,* D6-60240-1, The Boeing Company, February 1972.

29. Coordination Sheet SST-ANPD-150, "A Preliminary Acoustic Analysis of a 126-Tube, Area Ratio = 3.33 Jet Nozzle's Noise Characteristics (HM-AP-85)," E. A. Wolff and R. B. Tate, March 10, 1969.

30. Coordination Sheet SST-ANPD-176, "Preliminary Acoustic Analysis of an Investigation Test With a 126-Hole, Area Ratio = 2.8 Manhole Cover Suppressor," D. H. Underwood, June 11, 1969.

31. Coordination Sheet SST-ANPD-36, "Preliminary Analysis of the 24-Spoke (Area Ratio = 4.0) Nozzle Noise Suppression Characteristics," R. B. Tate, December 21, 1967.

32. Coordination Sheet SST-ANPD-185, "Repeatability of the 126-Tube (Area Ratio = 3.33) Nozzle Jet Noise Characteristics," R. B. Tate, July 25, 1969.

33. Coordination Sheet SST-ANPD-188, "Acoustic Evaluation of a 126 Elliptical Tube (AR = 2.8) Nozzle," R. B. Tate, July 30, 1969.

34. Coordination Sheet SST-ANPD-109, "A Preliminary Acoustic Analysis of a 36-Spoke, Area Ratio = 2.06 Jet Nozzle's Noise Characteristics (HM-AP-45)," C. P. Wright, September 26, 1968.

35. Coordination Sheet SST-ANPD-131, "Thrust Performance and Acoustic Characteristics of a Small-Scale 36-Spoke Suppressor Nozzle (J-93 Replica) (AR 2.08)," C. P. Wright and F. G. Strout, November 20, 1968.

36. J. E. Ffowcs-Williams, *Noise From Jet Aircraft in Flight*, Imperial College, London, January 1968.

37. Coordination Sheet SST-ANPD-133, "A Procedure for Determining Maximum Perceived Noise Levels (PNdB) at the 1500-foot Sideline," C. P. Wright, December 13, 1968.

APPENDIX A
SST 5 PNdB SUPPRESSION PROGRAM

This appendix lists most noise suppression hardware tested during the SST low-noise-suppression (5 PNdB) program. The test configurations and upstream flow conditions are included as well as available test references.

A.1 MODEL-SCALE (1/8TH) NOZZLE NOISE TESTS IN 1966

Facility: Boeing Annex D, Seattle

Acoustic Data Reference: Boeing Test Report T6A10341-1, "SST Engine Noise Suppression Study—Scale Model Tests," September 1966

Performance Data Reference: None

A.1.1 Test Hardware

A.1.1.1 Nozzles

Designation	Description
C-6	Round convergent nozzle with short conical plug equivalent to 1:8 scale of JT3C-6 turbojet engine nozzle; $D_T = 3.10$ in. ($A_T = 7.07$ in.^{2})
DP	Eight-lobe "daisy petal" exit configuration with 75% lobe penetration of the primary flow; $A_T = 7.07$ in.^{2}
MAE-2	Six-lobe spoke configuration with 30% lobe penetration of the primary flow; $A_T = 7.07$ in.^{2}
MAE-5	Six-pointed star configuration with 50% penetration of the primary flow; $A_T = 7.07$ in.^{2}
MPP 164	10 rounded lobe configuration with 12% penetration of the primary flow; $A_T = 7.07$ in.^{2}
7 tubes	Seven round convergent tubes of equal size; area ratio < 2.0, $A_T \simeq 7.07$ in.^{2}
21 tubes	21 round convergent tubes (10 tubes in first row, 10 tubes in second row, and one center tube), three different tube sizes; area ratio $\simeq 2.4$, $A_T \simeq 7.07$ in.^{2}
37 tubes	37 round convergent tubes (12 tubes in first row, 12 tubes in second row, 12 tubes in third row, and one center tube), four different tube sizes; $A_T \simeq$ 7.07 in.^{2}
820-STD	Round convergent nozzle; $D_T = 3.4$ in., $A_T = 9.079$ in.^{2}

Designation	Description
820-1	Six-spoke configuration with 20% lobe penetration of the primary flow; $A_T = 9.1$ in.^{2}
820-2	Six-spoke configuration with 50% lobe penetration of the primary flow; $A_T = 9.1$ in.^{2}
820-3	Four-spoke configuration with 50% lobe penetration of the primary flow; $A_T = 9.1$ in.^{2}
820-4	Eight-spoke configuration with 50% lobe penetration of the primary flow; $A_T = 9.1$ in.^{2}
820-5	Six-spoke configuration with 75% lobe penetration of the primary flow; $A_T = 9.1$ in.^{2}
GE-1 STD	Round convergent nozzle; $D_T = 4.25$ in., $A_T = 14.2$ in.^{2}
GE-2 STD	Round convergent nozzle; $D_T = 5.25$ in., $A_T = 21.6$ in.^{2}
GE-1	16-point star configuration, 12% penetration of the primary flow; $A_T = 14.2$ in.^{2}
GE-2	Eight-point star configuration, 30% penetration; $A_T = 21.6$ in.^{2}
GE-3	Eight-point reverse star configuration, 30% penetration; $A_T = 21.6$ in.^{2}
GE-4	Eight-point star configuration, 50% penetration; $A_T = 21.6$ in.^{2}
GE-5	16-point star configuration, 30% penetration; $A_T = 21.6$ in.^{2}
GE-6	16-point star, 50% penetration; $A_T = 21.6$ in.^{2}
GE-7	Four spokes, 30% penetration; $A_T = 21.6$ in.^{2}
GE-7A	Four spokes, 30% penetration, 1/8-in. step in ventilation gutter; $A_T = 21.6$ in.^{2}
GE-8	Four spokes, 50% penetration; $A_T = 21.6$ in.^{2}
GE-9	Four-lobe Maltese Cross, 30% penetration; $A_T = 21.6$ in.^{2}
GE-10	Four-lobe Maltese Cross, 50% penetration; $A_T = 21.6$ in.^{2}
GE-11	16-point star, 12% penetration; $A_T = 21.6$ in.^{2}
PW-P1	Round convergent nozzle; $D_T = 3.80$ in., $A_T = 11.33$ in.^{2}

Designation	Description
PW-P1B	Round nonconvergent nozzle; D_T = 3.80 in., A_T = 11.33 in.^{2}
PW-P2	Eight-point star, 30% penetration; A_T = 11.3 in.^{2}
PW-P3	Eight-point star, 50% penetration; A_T = 11.3 in.^{2}
PW-S1	Round convergent secondary-flow nozzle; D_T = 6.08 in.
PW-S2	Eight-point star secondary-flow nozzle, 30% penetration; A_T = PW-S1
PW-S3	Eight-point star secondary-flow nozzle, 50% penetration; A_T = PW-S1
PW-S4	Four-lobe Maltese Cross secondary-flow nozzle; A_T = PW-S1
PW-S5	J-85 round nozzle with steps; A_T = PW-S1

A.1.1.2 Ejectors

Designation	Description
GE-E1	Round ejector; D_I = 5.20 in., D_T = 4.75 in., D_E = 5.6 in., L = 7.1 in.
GE-E2	Round ejector; D_I = 8.38 in., D_T = 7.625 in., D_E = 7.56 in., L = 10.75 in.
GE-E3	Round ejector fitted with four or eight chutes; D_I = 8.38 in., D_T = 7.625 in., D_E = 7.56 in., L = 10.75 in.
GE-E4	Round ejector fitted with eight scoops 0.7 in. wide; D_I = 7.00 in.
GE-E5	Contoured four-lobe ejector; D_I = 4.20 in., D_T = 4.00 in., D_E = 4.20 in., L = 11.00 in.
PW-E1	Round ejector with 12 blow-in doors installed (BIDE); D_I = 9.25 in., D_T = 7.60 in., D_E = 8.55 in., L = 9.40 in.
PW-E1A	12-blow-in-door round ejector, plain "clamshell" with eight scoops 0.7 in. wide; D_I = 9.15 in., D_T = 7.62 in., D_E = 8.62 in., L = 9.35 in.
PW-E1B	12-blow-in-door round ejector, "scallop clamshell" with eight scoops 0.7 in. wide; dimensions same as ejector PW-E1A
PW-E1C	12-blow-in-door round ejector, no "clamshell," with eight scoops 0.7 in. wide; dimensions same as PW-E1A
PW-E4	Round ejector with eight scoops; D_I = 10.95 in., D_T = 10.00 in., D_E = 10.45 in., L = 10.50 in.
No. 5	This ejector was not identified in the acoustic data reference.

A.1.2 Test Configuration Index

Configuration	Primary nozzle	Secondary nozzle	Ejector	Ejector flow elements			Flow conditions
				Type	Quantity	Penetration	
1	C-6	None	None		None		GE: 1,2
2	C-6	None	No. 5		None		GE: 1,2
3	C-6	None	GE-1		None		GE: 1,2
4	C-6	None	GE-E1		None		GE: 1,2
5	DP	None	None		None		GE: 1,2
6	DP	None	No. 5		None		GE: 1,2
7	DP	None	GE-1		None		GE: 1,2
8	MAE-2	None	None		None		GE: 1,2
9	MAE-2	None	No. 5		None		GE: 1,2
10	MAE-2	None	GE-1		None		GE: 1,2
11	MAE-5	None	None		None		GE: 1,2
12	MAE-5	None	No. 5		None		GE: 1,2
13	MAE-5	None	GE-1		None		GE: 1,2
14	MPP 164	None	None		None		GE: 1,2
15	MPP 164	None	No. 5		None		GE: 1,2
16	MPP 164	None	GE-1		None		GE: 1,2
17	7 tubes	None	None		None		GE: 1,2
18	7 tubes	None	No. 5		None		GE: 1,2
19	7 tubes	None	GE-1		None		GE: 1,2
20	21 tubes	None	None		None		GE: 1,2
21	21 tubes	None	No. 5		None		GE: 1,2
22	21 tubes	None	GE-1		None		GE: 1,2
23	37 tubes	None	None		None		GE: 1,2
24	37 tubes	None	No. 5		None		GE: 1,2
25	37 tubes	None	GE-1		None		GE: 1,2
26	820-STD	None	None		None		GE: 1,2
27	820-STD	None	No. 5		None		GE: 1,2
28	820-STD	None	GE-1		None		GE: 1,2
29	820-1	None	None		None		GE: 1,2
30	820-1	None	No. 5		None		GE: 1,2
31	820-1	None	GE-1		None		GE: 1,2
32	820-2	None	None		None		GE: 1,2
33	820-2	None	No. 5		None		GE: 1,2
34	820-2	None	GE-1		None		GE: 1,2
35	820-3	None	None		None		GE: 1,2

Configuration	Primary nozzle	Secondary nozzle	Ejector	Ejector flow elements			Flow conditions
				Type	Quantity	Penetration	
36	820-3	None	No. 5		None		GE: 1,2
37	820-3	None	GE-1		None		GE: 1,2
38	820-4	None	None		None		GE: 1,2
39	820-4	None	No. 5		None		GE: 1,2
40	820-4	None	GE-1		None		GE: 1,2
41	820-5	None	None		None		GE: 1,2
42	820-5	None	No. 5		None		GE: 1,2
43	820-5	None	GE-1		None		GE: 1,2
44	GE-1 STD	None	None		None		GE: 2,3,4,5
45	GE-1 STD	None	GE-E1		None		GE: 2,3,4,5
46	GE-2 STD	None	None		None		GE: 2,3,4,5
47	GE-2 STD	None	GE-E2		None		GE: 2,3,4,5
48	GE-2 STD	None	GE-E3	Chutes	8	30%	GE: 2,3,4,5
49	GE-2 STD	None	GE-E4	Scoops	8	50%	GE: 2,3
50	GE-2 STD	None	GE-E4	Scoops	4	50%	GE: 2,3
51	GE-2 STD	None	GE-E4	Scoops	8	0%	GE: 2,3
52	GE-2 STD	None	GE-E4	Scoops	8	30%	GE: 2,3
53	GE-2 STD	None	GE-E4	Chutes	8	50%	GE: 2,3,4,5
54	GE-2 STD	None	GE-E4	Scoops Chutes	8 4	50% 50%	GE: 2,3
55	GE-2 STD	None	GE-E4	Scoops Chutes	4 8	50% 50%	GE: 2,3
56	GE-2 STD	None	GE-E4	Scoops Chutes	8 8	50% 50%	GE: 2,3
57	GE-2 STD	None	GE-E4	Scoops Chutes	8 8	0% 50%	GE: 2,3
58	GE-2 STD	None	GE-E3	Chutes	8	50%	GE: 2,3,4
59	GE-2 STD	None	GE-E3	Chutes	4	50%	GE: 2,3
60	GE-2 STD	None	GE-E3	None	None		GE: 2,3
61	GE-2 STD	None	GE-E3	Chutes	8	20%	GE: 2,3
62	GE-2 STD	None	GE-E3	Chutes	4	20%	GE: 2,3
63	GE-2 STD	None	GE-E3	Chutes	4	30%	GE: 2,3
64	GE-2 STD	None	GE-E3	Scoops	4	50%	GE: 2,3
65	GE-2 STD	None	GE-E3	Scoops	8	0%	GE: 2,3
66	GE-2 STD	None	GE-E3	Scoops	4	30%	GE: 2,3
67	GE-2 STD	None	GE-E3	Scoops	8	30%	GE: 2,3
68	GE-2 STD	None	GE-E3	Chutes	8	30%	GE: 2,3,4
69	GE-1	None	None		None		GE: 2,3,4,5

Configuration	Primary nozzle	Secondary nozzle	Ejector	Ejector flow elements			Flow conditions
				Type	Quantity	Penetration	
70	GE-1	None	GE-E1		None		GE: 2,3,4,5
71	GE-2	None	None		None		GE: 1,2,3
72	GE-2	None	GE-E2		None		GE: 1,2,3
73	GE-3	None	None		None		GE: 2,3
74	GE-3	None	GE-E2		None		GE: 2,3
75	GE-4	None	None		None		GE: 2,3
76	GE-4	None	GE-E2		None		GE: 2,3
77	GE-4	None	GE-E3	Chutes	8	50%	GE: 2,3
78	GE-5	None	None		None		GE: 2,3
79	GE-5	None	GE-E2		None		GE: 2,3
80	GE-5	None	GE-E3		None		GE: 2,3
81	GE-5	None	GE-E3	Chutes	8	60%	GE: 2,3
82	GE-6	None	None		None		GE: 1,2,3
83	GE-6	None	GE-E2		None		GE: 2,3
84	GE-6	None	GE-E3		None		GE: 1,2,3
85	GE-7	None	None		None		GE: 2,3
86	GE-7	None	GE-E2		None		GE: 2,3
87	GE-7A	None	None		None		GE: 2,3
88	GE-7A	None	GE-E2		None		GE: 2,3
89	GE-7A	None	GE-E3	Chutes	8	30%	GE: 2,3
90	GE-7A	None	GE-E3	Chutes	4	30%	GE: 2,3
91	GE-7A	None	GE-E3		None		GE: 2,3
92	GE-8	None	None		None		GE: 1,2,3
93	GE-8	None	GE-E2		None		GE: 2,3
94	GE-8	None	GE-E3	Chutes	8	30%	GE: 1,2,3
95	GE-8	None	GE-E5		None		GE: 2,3
96	GE-8	None	GE-E3	Chutes	8	50%	GE: 2,3,4
97	GE-9	None	None		None		GE: 2,3,4
98	GE-9	None	GE-E2		None		GE: 2,3,4
99	GE-10	None	None		None		GE: 2,3,4
100	GE-10	None	GE-E3		None		GE: 2,4,5
101	GE-10	None	GE-E3	Chutes	4	30%	GE: 2,3
102	GE-11	None	None		None		GE: 2,3
103	GE-11	None	GE-E2		None		GE: 2,3
104	GE-11	None	GE-E3	Chutes	8	30%	GE: 2,3,4
105	GE-11	None	GE-E4	Chutes	8	50%	GE: 2,3
106	GE-11	None	GE-E4	Chutes	4	50%	GE: 2,3

Configuration	Primary nozzle	Secondary nozzle	Ejector	Ejector flow elements			Flow conditions
				Type	Quantity	Penetration	
107	GE-11	None	GE-E4		None		GE: 2,3
108	GE-11	None	GE-E4	Scoops	8	50%	GE: 2,3
109	GE-11	None	GE-E4	Scoops	4	50%	GE: 2,3
110	GE-11	None	GE-E4	Chutes	4	85%	GE: 2,3
111	GE-11	None	GE-E4	Chutes	2	85%	GE: 2,3
112	PW-P1	PW-S1	None		None		PW: 1,2,3
113	PW-P1	PW-S3	None		None		PW: 1,2,3
114	PW-P1	PW-S2	PW-E1		None		PW: 1,2
115	PW-P1	PW-S1	PW-E4	Scoops	8	0%	PW: 2,3
116	PW-P1	PW-S1	PW-E4	Scoops	4	74%	PW: 2,3
117	PW-P1	PW-S1	PW-E4	Scoops	8	74%	PW: 2,3
118	PW-P1	PW-S3	PW-E4	Scoops	4	74%	PW: 2,3
119	PW-P1	PW-S3	PW-E1	Scoops	8	74%	PW: 2,3
120	PW-P1	PW-S3	PW-E1	Scoops	4	74%	PW: 2,3
123	PW-P1	PW-S3	PW-E1		None		PW: 2,3
124	PW-P1	PW-S3	PW-E1	Scoops	4	22%	PW: 2
125	PW-P1	PW-S1	PW-E4	Scoops	4	30%	PW: 2,3
126	PW-P1	PW-S1	PW-E4	Scoops	8	58%	PW: 2,3
127	PW-P1	PW-S1	PW-E1B	Scoops	8	50%	PW: 2,3
128	PW-P1	PW-S5	None		None		PW: 2,3
129	PW-P1	PW-S5	PW-E1C	Scoops	8	50%	PW: 2,3
130	PW-P1	PW-S5	PW-E1C	Scoops	4	50%	PW: 2,3
131	PW-P1	PW-S5	PW-E1C	Scoops	4	0%	PW: 2,3
132	PW-P1	PW-S5	PW-E1A	Scoops	8	0%	PW: 2,3
133	PW-P1	PW-S5	PW-E1A	Scoops	4	0%	PW: 2,3
134	PW-P1	PW-S5	PW-E1A	Scoops	8	50%	PW: 2,3
135	PW-P1	PW-S5	PW-E1B	Scoops	8	50%	PW: 2,3
136	PW-P1	PW-S5	PW-E1B	Scoops	4	50%	PW: 2,3
137	PW-P1	PW-S5	PW-E1B	Scoops	8	0%	PW: 2,3
138	PW-P1	PW-S1	GE-E4	Chutes	8	50%	PW: 2,3
139	PW-P1	PW-S1	GE-E4	Scoops	8	60%	PW: 2,3
140	PW-P1	PW-S1	GE-E4	Scoops	8	100%	PW: 2
141	PW-P1	PW-S1	GE-E3	Chutes	4	50%	PW: 2,3
142	PW-P1	PW-S1	GE-E3		None		PW: 2,3
143	PW-P1	PW-S1	GE-E3	Chutes	8	50%	PW: 2,3
145	PW-P1	PW-S5	GE-E3	Chutes	4	50%	PW: 2,3
146	PW-P1	PW-S5	GE-E3	Chutes	2	50%	PW: 2,3

Configuration	Primary nozzle	Secondary nozzle	Ejector	Ejector flow elements			Flow conditions
				Type	Quantity	Penetration	
147	PW-P1	PW-S5	GE-E3		None		PW: 2,3
148	PW-P1	PW-S1	PW-E1A	Chutes	8	50%	PW: 2,3
149	PW-P1	PW-S1	PW-E1A	Chutes	4	50%	PW: 2,3
150	PW-P1	PW-S1	PW-E1A		None		PW: 2,3
151	PW-P1	PW-S1	PW-E1A	Scoops	4	50%	PW: 2,3
152	PW-P1	PW-S1	PW-E1A	Scoops	8	50%	PW: 2,3
153	PW-P1	PW-S1	PW-E1C		None		PW: 2,3
154	PW-P1	PW-S1	None		None		PW: 2,3 (secondary flow only)
155	PW-P1	PW-S1	None		None		PW: 2,3 (primary flow only)
156	PW-P1B	None	None		None		PW: 2
157	PW-P1B	PW-S4	None		None		PW: 2,3
158	PW-P1B	PW-S4	PW-E1		None		PW: 2,3
159	PW-P1B	PW-S1	PW-E1		None		PW: 2,3
160	PW-P1B	PW-S1	None		None		PW: 2,3
161	PW-P1B	PW-S5	PW-E1		None		PW: 2,3
162	PW-P1B	PW-S5	None		None		PW: 2,3
163	PW-P1B	PW-S1	PW-E4	Scoops	8	58%	PW: 2,3
164	PW-P1B	PW-S1	PW-E4	Scoops	8	30%	PW: 2,3
165	PW-P1B	PW-S1	PW-E4	Scoops	8	0%	PW: 2,3
166	PW-P1B	PW-S1	PW-E4	Scoops	4	30%	PW: 2,3
167	PW-P1B	PW-S1	PW-E4	Scoops	4	58%	PW: 2,3
168	PW-P1B	PW-S1	PW-E4	Scoops	4	0%	PW: 2,3
169	PW-P1B	PW-S4	PW-E1B	Scoops	8	50%	PW: 2,3
170	PW-P1B	PW-S4	PW-E1B	Scoops	4	50%	PW: 2,3
171	PW-P1B	PW-S4	PW-E1B	Scoops	8	0%	PW: 2,3
172	PW-P1B	PW-S4	None		None		PW: 2,3
173	PW-P1B	PW-S5	PW-E1A	Scoops	8	0%	PW: 2,3
174	PW-P1B	PW-S5	PW-E1A	Scoops	4	50%	PW: 2,3
175	PW-P1B	PW-S1	GE-E3	Chutes	8	50%	PW: 2,3
176	PW-P1B	PW-S1	GE-E3	Chutes	4	50%	PW: 2,3
177	PW-P1B	PW-S4	GE-E3	Chutes	8	50%	PW: 2,3
178	PW-P1B	PW-S4	GE-E3	Chutes	4	50%	PW: 2,3
179	PW-P1B	PW-S4	GE-E3		None		PW: 2,3
180	PW-P1B	PW-S4	GE-E3	Chutes	2	50%	PW: 2,3

Configuration	Primary nozzle	Secondary nozzle	Ejector	Ejector flow elements			Flow conditions
				Type	Quantity	Penetration	
181	PW-P2	PW-S2	None		None		PW: 1,2
182	PW-P2	PW-S1	PW-E1		None		PW: 1,2
183	PW-P2	PW-S2	PW-E1		None		PW: 1,2
184	PW-P3	PW-S3	None		None		PW: 2
185	PW-P3	PW-S3	PW-E4	Scoops	8	74%	PW: 3

A.1.3 Upstream Flow Conditions

A.1.3.1 GE Nozzles (Primary Flow Only)

Reference number	Pressure ratio	Total temperature (°F)
1	1.88	900
2	3.14	1,600
3	3.01	2,100
4	3.01	2.500
5	3.01	2,785

A.1.3.2 P&WA Nozzles

Reference number	Primary flow		Secondary flow	
	Pressure ratio	Total temperature (°F)	Pressure ratio	Total temperature (°F)
1	1.88	1,560	2.67	Cold
2	2.14	1,590	2.35	2,000
3	2.14	1,590	2.32	2,500
4	2.14	1,590	2.67	2,250
5	2.14	1,590	2.67	3,150

A.2 MODEL-SCALE (1/8TH) NOZZLE NOISE TESTS IN 1967

Facility: Boeing Annex D, Seattle

Acoustic Data Reference: Boeing Test Report T6A11035-1, "Scale Model Jet Noise Suppression Program," March 1968

Performance Data Reference: None

A.2.1 Test Hardware

A.2.1.1 Nozzles

Designation	Description
1	Round convergent nozzle; $D_T = 4.10$ in., $A_T = 13.2$ in.^{2}
3	16-pointed star configuration with 12% penetration of the primary flow; $A_T = 12.5$ in.^{2}
4	16-pointed star configuration with 12% penetration of the primary flow; $A_T = 14.1$ in.^{2}
6	Four-lobe nozzle configuration with 50% penetration of the primary flow, the lobes having parallel sides
7	GE-2 standard, round convergent nozzle; $D_T = 5.31$ in., $A_T = 21.6$ in.^{2}
TSEN-2	Round convergent nozzle used in conjunction with TSEN-2 ejector; $D_T = 4.67$ in., $A_T = 17.35$ in.^{2}

A.2.1.2 Ejectors

	Description				
	Diameter (in.)			Length (in.)	
Designation	Throat	Inlet	Exit	Inlet to throat	Total
1	4.90	6.46	5.40	2.60	7.65
2	4.95	6.86	4.95	2.80	8.50
4	4.90	6.46	6.86	2.60	7.65
5	4.95	6.86	4.95	2.80	8.44
	Fiberglass lined				
6	6.35	7.30	6.35	2.98	9.10
8	6.35	7.30	6.35	3.00	9.10
	Fiberglass lined				
B	7.45	8.35	7.85	2.56	10.5
C	10.05	10.95	10.70	2.20	10.50
D	5.33	6.95	6.40	2.70	8.07
E	5.33	6.95	6.40	2.70	8.07
	Tail feather penetration 30% with modified tips				
F	5.33	6.95	6.40	2.70	8.07
	Tail feather penetration 15.6%				
G	5.04	7.28	5.04	1.60	7.37
	GE 1/8-scale prototype ejector (convergent-divergent-convergent)				
H	5.04	7.28	6.05	1.60	7.37
	GE 1/8-scale prototype ejector (convergent-divergent)				
I	5.33	6.95	6.40	2.70	8.07
	Tail feather penetration 30% with straight tips				
TSEN-2	5.60	7.24	5.60	2.50	7.06

A.2.1.3 Chutes

Designation	Description		
	Type	Dimensions (in.)	
		Width	Length
1	Cone chutes	0.31	2.16
2	Cone chutes	0.45	2.16
3	Cone chutes	0.51	2.16
5	Flat chutes	0.45	2.16
6	Flat chutes	0.90	2.16
7	Flat chutes	1.80	2.16
8	Flat chutes with sides	0.45	2.95
9	Flat chutes with sides	0.45	2.68
10	Flat chutes with sides	0.45	2.16
11	Tapered box chutes	NIA	2.95
12	Rectangular box chutes	0.45	2.16
13	Wing chutes	0.50	2.16
14	Flat chutes with sides	0.45	3.48
15	Rectangular box chutes	0.45	3.48
16	Wing chutes	0.45	3.48
17	Aerodynamic cone chutes	0.7	3.50
18	U-shaped scoops	1.0	3.75
19	Aerodynamic cone chutes	0.5	2.52
20	Ejectorless chute cluster	0.45	2.00
21	Flat chutes with sides	0.45	2.23
22	Flat chutes with sides	0.378	2.66
23	Flat chutes with sides	0.325	3.09
24	Flat chutes with sides	0.285	3.52
25	Flat chutes with sides	0.254	3.95
32	Flat chutes with sides	0.45	1.94
Special	Flat chutes with sides Quantity (8) 40% penetration 22.4% area blockage Nozzle exit plane to throat distance (2-1/4 in.)	0.45	Various
TSEN-2	Flat chutes with sides	0.54	2.95
TSEN-2	Triangular chutes without sides	1.10 (Base)	2.98 (Outer edge)

Test Configuration Index

Configu-ration	Nozzle identification number	Ejector identification number	Ejector flow elements					Flow conditions	
			Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Total temperature (°F)	Pressure ratio
1	1	1	1	4	40	30	7.7	2,540	2.2, 2.5, 2.7
2	1	1	1	8	40	30	15.4	2,540	2.2, 2.5, 2.7
3	1	1	2	8	30	23	16.8	2,540	2.2, 2.5, 2.7, 3.0
4	1	1	2	8	40	30	22.4	2,540	2.2, 2.5, 2.7
5	1	1	2	8	50	36	27.9	2,540	2.0, 2.2, 2.7, 3.0
6	1	1	2	2	40	30	5.6	2,540	2.7
7	1	1	2	4	40	30	11.2	2,540	2.7
8	1	1	3	8	30	23	19.0	2,540	2.0, 2.2, 2.7, 3.0
9	1	1	3	8	40	30	25.3	2,540	2.0, 2.2, 2.7, 3.0
10	1	1	3	8	50	36	31.7	2,540	2.0, 2.2, 2.7, 3.0
11	1	1	3	4	40	30	12.7	2,540	2.7
12	1	1	3	2	40	30	6.3	2,540	2.7
13	1	1	5	8	30	23	16.8	2,540	2.2, 2.5, 2.7
14	1	1	5	8	40	30	22.4	2,540	2.2, 2.5, 2.7
15	1	1	5	8	50	36	27.9	2.540	2.2, 2.5, 2.7
16	1	1	5	4	40	30	11.2	2,540	2.2, 2.5, 2.7
17	1	1	5	2	40	30	5.6	2,540	2.7
18	1	1	6	4	40	30	22.4	2,540	2.7
19	1	1	6	2	40	30	11.9	2,540	2.7
20	1	1	7	2	40	30	22.4	2,540	2.7
21	1	2	8	8	30	17	16.8	2,540	2.0, 2.7, 3.0
Blow-in doors									
22	1	2	8	8	30	17	16.8	2,540	2.0, 2.7, 3.0
Cylindrical extension on ejector, blow-in doors									

Test Configuration Index (continued)

Configuration	Nozzle identification number	Ejector identification number	Ejector flow elements: Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Flow conditions: Total temperature (°F)	Pressure ratio
23	3	6	8	8	30	18	16.8	2,540	2.0, 2.7, 3.0
24	4	2	8	8	30	17	16.8	2,540	2.0, 2.6, 3.0
25	4	6	8	8	30	18	16.8	2,540	2.0, 2.7, 3.0
Cylindrical extension on ejector, blow-in doors									
26	4	6	8	8	30	18	16.8	2,540	2.0, 2.7
Blow-in doors									
27	1	2	8	8	40	20	22.4	2,540	2.0, 2.7, 3.0
28	1	2	8	8	40	20	22.4	2,540	2.0, 2.7, 3.0
Cylindrical extension on ejector, blow-in doors									
29	3	6	8	8	40	22	22.4	2,540	2.0, 2.7, 3.0
30	1	2	8	8	50	26	27.9	2,540	2.0, 2.7, 3.0
Blow-in doors									
31	1	2	8	8	50	26	27.9	2,540	2.0, 2.7, 3.0
Cylindrical extension on ejector, blow-in doors									
32	3	6	8	8	50	26	27.9	2,540	2.0, 2.7, 3.0
33	4	5	8	8	50	26	27.9	2,540	2.0, 2.7, 3.0
34	4	5	8	8	50	26	27.9	2,540	2.0, 2.2, 2.5, 2.7, 3.0
Ejector wall hard-lined									
35	4	5	8	8	50	26	27.9	2,540	2.2, 2.5, 2.7
Forward half of ejector wall hard-lined									

Test Configuration Index (continued)

Configuration	Nozzle identification number	Ejector identification number	Ejector flow elements: Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Flow conditions: Total temperature (°F)	Pressure ratio
36	4	5	8	8	50	26	27.9	2,540	2.2, 2.7, 3.0
Aft half of ejector wall hard-lined									
37	4	5	8	8	50	26	27.9	2,540	2.2, 2.5, 2.7
Ejector wall hard-lined									
38	1	4	9	8	30	19	16.8	2,540	2.0, 2.7, 3.0
39	1	4	9	8	30	19	16.8	2,540	2.0, 2.7, 3.0
Cylindrical extension on ejector									
40	1	0	9	8	30	19	16.8	2,540	2.7, 3.0, 3.3
No ejector									
41	1	4	9	8	40	24	22.4	2,540	2.0, 2.7, 3.0
42	1	4	9	8	40	24	22.4	2,540	2.0, 2.7, 3.0
Cylindrical extension on ejector									
43	1	D	9	8	40	24	22.4	2,540	2.7, 3.0, 3.3
Chutes in line with penetrating tail feather									
44	1	E	9	8	40	24	22.4	2,540	2.7, 3.0, 3.3
Chutes in line with penetrating tail feather									
45	1	E	9	8	40	24	22.4	2,540	2.7, 3.0, 3.3
Chutes out of line with penetrating tail feather									

Test Configuration Index (continued)

Configuration	Nozzle identification number	Ejector identification number	Ejector flow elements: Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Flow conditions: Total temperature (°F)	Pressure ratio
46	1	F	9	8	40	24	22.4	2,540	2.7, 3.0, 3.3
Chutes in line with penetrating tail feathers									
47	1	F	9	8	40	24	22.4	2,540	2.7, 3.0, 3.3
Chutes out of line with penetrating tail feathers									
48	1	1	9	8	40	24	22.4	2,540	2.7, 3.0, 3.3
Chutes in line with penetrating tail feathers									
49	1	1	9	8	40	24	22.4	2,540	2.7, 3.0, 3.3
Chutes out of line with penetrating tail feathers									
50	1	4	9	8	50	28	27.9	2,540	2.0, 2.7, 3.0
51	1	4	9	8	50	28	27.9	2,540	2.0, 2.7, 3.0
Cylindrical extension on ejector									
52	1	1	10	8	30	19	16.8	2,540	2.0, 2.7, 3.0
53	1	1	10	8	40	24	22.4	2,540	2.0, 2.7, 3.0
54	1	2	10	8	40	30	22.4	2,540	2.0, 2.2, 2.7, 3.0
55	1	6	10	8	40	31	22.4	2,540	2.0, 2.2, 2.7, 3.0
56	4	6	10	8	40	31	22.4	2,540	2.0, 2.2, 2.7, 3.0
57	1	1	10	8	50	30	27.9	2,540	2.0, 2.7, 3.0
58	1	2	11	8	30	17	26.1	2,540	2.0, 2.7, 3.0
59	1	2	11	8	30	17	26.1	2,540	2.0, 2.7, 3.0
Cylindrical extension on ejector									
60	4	2	11	8	30	17	26.1	2,540	2.0, 2.6, 3.0
Blow-in doors									

Test Configuration Index (continued)

Configuration	Nozzle identification number	Ejector identification number	Ejector flow elements: Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Flow conditions: Total temperature (°F)	Pressure ratio
61	4	2	11	8	30	17	26.1	2,540	2.0, 2.6, 3.0
Cylindrical extension on ejector, blow-in doors									
62	1	2	11	8	40	20	34.8	2,540	2.0, 2.7, 3.0
Blow-in doors									
63	1	2	11	8	40	20	34.8	2,540	2.0, 2.7, 3.0
Cylindrical extension on ejector, blow-in doors									
64	1	2	11	8	50	26	43.5	2,540	2.0, 2.7, 3.0
Blow-in doors									
65	1	1	12	8	30	19	16.8	2,540	2.0, 2.7
66	1	2	12	8	30	24	16.8	2,540	2.0, 2.2, 2.7, 3.0
67	1	2	12	8	30	24	16.8	2,540	3.0
Forced water injection into chutes									
68	1	2	12	8	30	24	16.8	2,540	2.0, 2.2, 2.7, 3.0
Forced air into chutes									
69	1	4	12	8	40	30	22.4	2,540	2.0, 2.2, 2.7, 3.0
70	1	4	12	8	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
Cylindrical extension on ejector									
71	1	1	12	8	40	24	22.4	2,540	2.0, 2.7, 3.0
72	1	2	12	8	40	25	22.4	2,540	2.0, 2.2, 2.7, 3.0
73	1	2	12	8	40	30	22.4	2,540	3.0
Forced water injection into chutes									

Test Configuration Index (continued)

Configuration	Nozzle identification number	Ejector identification number	Ejector flow elements: Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Flow conditions: Total temperature (°F)	Pressure ratio
74	1	2	12	8	40	30	22.4	2,540	2.0, 2.2, 2.7, 3.0
Forced air into chutes									
75	1	1	12	8	50	30	27.9	2,540	2.0, 2.7, 3.0
76	1	1	13	8	40	30	24.8	2,540	2.7
								1,600, 1,700	2.5
								1,800, 1,900	2.5
								2,000, 2,100	2.5
								2,200, 2,300	2.5
								2,400, 2,500	2.5
								2,600	2.5
77	1	1	13	8	50	36	31	2,540	2.2, 2.5, 2.7
78	1	1	13	4	40	30	12.4	2,540	2.7
79	1	1	13	2	40	30	6.2	2,540	2.7
80	1	2	14	8	40	18	22.4	2,540	2.0, 2.2, 2.7, 3.0
81	1	6	14	8	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance (coplanar)									
82	1	6	14	8	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 3/4 in.									
83	1	6	14	8	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 1-1/2 in.									
84	1	6	14	8	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 2-1/4 in.									

Test Configuration Index (continued)

Configuration	Nozzle identification number	Ejector identification number	Ejector flow elements: Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Flow conditions: Total temperature (°F)	Pressure ratio
85	1	6	14	8	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 3 in.									
86	1	6	14	8	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: coplanar; chute location: 1/2 in. downstream									
87	1	6	14	8	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 3/4 in.; chute location: 1/2 in. downstream									
88	1	6	14	8	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 1-1/2 in.; chute location: 1/2 in. downstream									
89	1	6	14	8	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 2-1/4 in.; chute location: 1/2 in. downstream									
90	1	6	14	8	40	20	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 3 in.; chute location: 1/2 in. downstream									
91	1	6	14	8	40	22	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: coplanar; chute location: 1 in. downstream									
92	1	6	14	8	40	22	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 3/4 in.; chute location: 1 in. downstream									
93	1	6	14	8	40	22	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 1-1/2 in.; chute location: 1 in. downstream									

Test Configuration Index (continued)

Configuration	Nozzle identification number	Ejector identification number	Ejector flow elements: Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Flow conditions: Total temperature (°F)	Pressure ratio
94	1	6	14	8	40	22	22.4	2,540	2.0, 2.2, 2.7, 3.0
	Nozzle exit plane to throat distance: 2-1/4 in.; chute location: 1 in. downstream								
95	1	6	14	8	40	22	22.4	2,540	2.0, 2.2, 2.7, 3.0
	Nozzle exit plane to throat distance: 3 in.; chute location: 1 in. downstream								
96	1	6	14	8	40	23	22.4	2,540	2.0, 2.2, 2.7, 3.0
	Nozzle exit plane to throat distance: coplanar; chute location: 1-1/2 in. downstream								
97	1	6	14	8	40	23	22.4	2,540	2.0, 2.2, 2.7, 3.0
	Nozzle exit plane to throat distance: 3/4 in.; chute location: 1-1/2 in. downstream								
98	1	6	14	8	40	23	22.4	2,540	2.0, 2.2, 2.7, 3.0
	Nozzle exit plane to throat distance: 1-1/2 in.; chute location: 1-1/2 in. downstream								
99	1	6	14	8	40	23	22.4	2,540	2.0, 2.2, 2.7, 3.0
	Nozzle exit plane to throat distance: 2-1/4 in.; chute location: 1-1/2 in. downstream								
100	1	6	14	8	40	23	22.4	2,540	2.0, 2.2, 2.7, 3.0
	Nozzle exit plane to throat distance: 3 in.; chute location: 1-1/2 in. downstream								
101	1	6	14	8	40	19	22.4	2,540	2.0, 2.2, 2.7, 3.0
	Nozzle exit plane to throat distance: 3/4 in.; chute location: 1/2 in. upstream								
102	1	6	14	8	40	19	22.4	2,540	2.0, 2.2, 2.7, 3.0
	Nozzle exit plane to throat distance: 1-1/2 in.; chute location: 1/2 in. upstream								

Test Configuration Index (continued)

Configuration	Nozzle identification number	Ejector identification number	Ejector flow elements: Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Flow conditions: Total temperature (°F)	Pressure ratio
103	1	6	14	8	40	19	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 2-1/4 in.; chute location: 1/2 in. upstream									
104	1	6	14	8	40	19	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 3 in.; chute location: 1/2 in. upstream									
105	1	6	14	8	40	18	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 1-1/2 in.; chute location: 1 in. upstream									
106	1	6	14	8	40	18	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 2-1/4 in.; chute location: 1 in. upstream									
107	1	6	14	8	40	18	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 3 in.; chute location: 1 in. upstream									
108	1	6	14	8	40	13	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 1-1/2 in.; chute location: 1-1/2 in. upstream									
109	1	6	14	8	40	13	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 2-1/4 in.; chute location: 1-1/2 in. upstream									
110	1	6	14	8	40	13	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 3 in.; chute location: 1-1/2 upstream									
111	1	6	14	8	40	13	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 2-1/4 in.; chute location: 2 in. upstream									

Test Configuration Index (continued)

Configuration	Nozzle identification number	Ejector identification number	Ejector flow elements: Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Flow conditions: Total temperature (°F)	Pressure ratio
112	1	6	14	8	40	13	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 3 in.; chute location: 2 in. upstream									
113	1	6	14	8	40	24	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: coplanar; chute location: 2 in. downstream									
114	1	6	14	8	40	24	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 3/4 in.; chute location: 2 in. downstream									
115	1	6	14	8	40	24	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 1-1/2 in.; chute location: 2 in. downstream									
116	1	6	14	8	40	24	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 2-1/4 in.; chute location: 2 in. downstream									
117	1	6	14	8	40	24	22.4	2,540	2.0, 2.2, 2.7, 3.0
Nozzle exit plane to throat distance: 3 in.; chute location: 2 in. downstream									
118	1	8	14	8	40	19	22.4	2,540	2.0, 2.2, 2.7, 3.0
Ejector wall hard-lined									
119	4	8	14	8	40	19	22.4	2,540	2.0, 2.2, 2.7, 3.0
Ejector wall hard-lined									
120	1	2	15	8	40	18	22.4	2,540	2.0, 2.2, 2.7, 3.0
Ejector wall hard-lined									

Test Configuration Index (continued)

Configu-ration	Nozzle identification number	Ejector identification number	Ejector flow elements					Flow conditions	
			Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Total temperature (°F)	Pressure ratio
121	1	8	15	8	40	19	22.4	2,540	2.0, 2.2, 2.7, 3.0
Ejector wall hard-lined, divergent-lined extension on ejector									
122	1	8	15	8	40	19	22.4	2,540	2.0, 2.2, 2.7, 3.0
Ejector wall hard-lined									
123	1	1	16	8	40	18	22.4	2,540	2.0, 2.2, 2.7, 3.0
124	1	8	16	8	40	19	22.4	2,540	2.0, 2.2, 2.7, 3.0
Divergent-lined extension on ejector									
125	1	8	16	8	40	19	22.4	2,540	2.0, 2.2, 2.7, 3.0
Ejector wall hard-lined									
126	1	8	16	8	40	19	22.4	2,540	2.0, 2.2, 2.7, 3.0
Ejector wall hard-lined, divergent extension on ejector									
127	4	8	16	8	40	19	22.4	2,540	2.0, 2.2, 2.7, 3.0
Ejector wall hard-lined									
128	6	8	16	4	40	19	11.2	2,540	2.0, 2.2, 2.7, 3.0
Ejector wall hard-lined, chutes in line with nozzle lobes									
129	6	8	16	4	60	26	16.8	2,540	2.0, 2.2, 2.7, 3.0

Test Configuration Index (continued)

Configuration	Nozzle identification number	Ejector identification number	Ejector flow elements: Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Flow conditions: Total temperature (°F)	Pressure ratio
130	7	B	17	8	30	14	26.1	2,540	2.2, 3.0
131	7	B	17	8	40	18	34.8	2,540	2.2, 3.0
132	7	C	18	8	20	N/A	24.8	2,540	2.2, 3.0
133	7	C	18	8	50	N/A	62.1	2,540	2.2, 3.0
134	1	2	19	8	40	26	24.8	2,540	2.2, 3.0
135	1	4	19	8	40	25	24.8	2,540	2.0, 2.2, 2.7, 3.0
136	1	6	19	8	40	26	24.8	2,540	2.0, 2.2, 2.7, 3.0
137	1	0	20	8	40	30	22.4	2,540	2.7, 3.0, 3.3
138	1	0	20	8	40	30	22.4	2,540	2.7, 3.0, 3.3
			Chute location: 1/2 in. downstream						
139	1	0	20	8	40	30	22.4	2,540	2.7, 3.0, 3.3
			Chute location: 1 in. downstream						
140	1	0	20	8	40	30	22.4	2,540	2.7, 3.0, 3.3
			Chute location: 1-1/2 in. downstream						
141	1	0	20	8	40	30	22.4	2,540	2.7, 3.0, 3.3
			Chute location: 2 in. downstream						
142	1	0	20	8	40	30	22.4	2,540	2.7, 3.0, 3.3
			Chute location: 2-1/2 in. downstream						
143	1	0	20	8	40	30	22.4	2,540	2.7, 3.0, 3.3
			Chute location: 3 in. downstream						

Test Configuration Index (continued)

Configu-ration	Nozzle identification number	Ejector identification number	Ejector flow elements: Chute identification number	Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Flow conditions: Total temperature (°F)	Pressure ratio
144	1	0	20	8	40	30	22.4	2,540	2.7, 3.0, 3.3
Chute location: 3-1/2 in. downstream									
145	1	0	20	8	40	30	22.4	2,540	2.7, 3.0, 3.3
Chute location: 4 in. downstream									
146	1	G	21	8	40	30	22.5	2,540	2.0, 2.2, 2.7, 3.0, 3.3
147	1	G	22	8	50	30	22.5	2,540	2.0, 2.2, 2.7, 3.0, 3.3
148	1	G	23	8	60	30	22.5	2,540	2.0, 2.2, 2.7, 3.0, 3.3
149	1	G	24	8	70	30	22.5	2,540	2.0, 2.2, 2.7, 3.0, 3.3
150	1	G	25	8	80	30	22.5	2,540	2.0, 2.2, 2.7, 3.0, 3.3
151	1	G	32	8	40	30	22.5	2,540	2.0, 2.2, 2.7, 3.0, 3.3
152	1	H	32	8	40	30	22.5	2,54[illegible]	2.0, 2.2, 2.7, 3.0, 3.3

Test Configuration Index (continued)

Configuration	Nozzle identification number	Ejector identification number	Ejector flow elements: Chute identification number	Angle of attack (deg)	Chute length (in.)	Chute location (in.)	Ejector slots	Flow conditions: Total temperature (°F)	Pressure ratio
153	1	6	Special	11.7	4.5	1-1/2 upstream	Open	2,540	3.0
154	1	6	Special	11.7	4.5	1-1/2 upstream	Closed	2,540	3.0
155	1	6	Special	14.1	4.5	At throat	Closed	2,540	3.0
156	1	6	Special	14.1	4.5	At throat	Open	2,540	3.0
157	1	6	Special	16.5	4.5	1-1/2 downstream	Closed	2,540	3.0
158	1	6	Special	16.5	4.5	1-1/2 downstream	Open	2,540	3.0
159	1	6	Special	18.7	4.0	1-1/2 downstream	Closed	2,540	3.0
160	1	6	Special	18.7	4.0	1-1/2 downstream	Open	2,540	3.0
161	1	6	Special	15.9	4.0	At throat	Closed	2,540	3.0
162	1	6	Special	15.9	4.0	At throat	Open	2,540	3.0
163	1	6	Special	13.2	4.0	1-1/2 upstream	Closed	2,540	3.0
164	1	6	Special	13.2	4.0	1-1/2 upstream	Open	2,540	3.0
165	1	6	Special	15.1	3.5	1-1/2 upstream	Closed	2,540	3.0
166	1	6	Special	15.1	3.5	1-1/2 upstream	Open	2,540	3.0
167	1	6	Special	18.3	3.5	At throat	Closed	2,540	3.0
168	1	6	Special	18.3	3.5	At throat	Open	2,540	3.0
169	1	6	Special	21.5	3.5	1-1/2 downstream	Closed	2,540	3.0
170	1	6	Special	21.5	3.5	1-1/2 downstream	Open	2,540	3.0
171	1	6	Special	25.3	3.0	1-1/2 downstream	Closed	2,540	3.0
172	1	6	Special	25.3	3.0	1-1/2 downstream	Open	2,540	3.0
173	1	6	Special	21.5	3.0	At throat	Closed	2,540	3.0
174	1	6	Special	21.5	3.0	At throat	Open	2,540	3.0
175	1	6	Special	17.1	3.0	1-1/2 upstream	Closed	2,540	3.0

Test Configuration Index (continued)

Configu-ration	Nozzle identification number	Ejector identification number	Ejector flow elements: Chute identification number	Angle of attack (deg)	Chute length (in.)	Chute location (in.)	Ejector slots	Flow conditions: Total temperature (°F)	Pressure ratio
176	1	6	Special	17.7	3.0	1-1/2 upstream	Open	2,540	3.0
177	1	6	Special	21.4	2.5	1-1/2 upstream	Closed	2,540	3.0
178	1	6	Special	21.4	2.5	1-1/2 upstream	Open	2,540	3.0
179	1	6	Special	26.0	2.5	At throat	Closed	2,540	3.0
180	1	6	Special	26.0	2.5	At throat	Open	2,540	3.0
181	1	6	Special	30.1	2.5	1-1/2 downstream	Closed	2,540	3.0
182	1	6	Special	30.1	2.5	1-1/2 downstream	Open	2,540	3.0
183	1	6	Special	39.8	2.0	1-1/2 downstream	Closed	2,540	3.0
184	1	6	Special	39.8	2.0	1-1/2 downstream	Open	2,540	3.0
185	1	6	Special	33.3	2.0	At throat	Closed	2,540	3.0
186	1	6	Special	33.3	2.0	At throat	Open	2,540	3.0
187	1	6	Special	27.1	2.0	1-1/2 upstream	Closed	2,540	3.0
188	1	6	Special	27.1	2.0	1-1/2 upstream	Open	2,540	3.0
189	1	6	Special	37.4	1.5	1-1/2 upstream	Closed	2,540	3.0
190	1	6	Special	37.4	1.5	1-1/2 upstream	Open	2 540	3.0
191	1	6	Special	47.0	1.5	At throat	Closed	2,540	3.0
192	1	6	Special	47.0	1.5	At throat	Open	2,540	3.0
193	1	6	Special	58.5	1.5	1-1/2 downstream	Closed	2,540	3.0
194	1	6	Special	58.5	1.5	1-1/2 downstream	Closed	2,540	3.0

Test Configuration Index (continued)

Configuration	Nozzle ejector identification number	Ejector flow elements				Flow conditions	
		Quantity	Penetration (%)	Angle of attack (deg)	Blockage (%)	Total temperature (°F)	Pressure ratio
195	TSEN-2	6	50	24	25	1,140, 1,640, 2,040 1,670, 2,090 2,340	2.0 3.0 2.7, 3.0, 3.2
196	TSEN-2	8	50	24	33	2,340	2.7, 3.0, 3.2
			Flat chutes with sides				
197	TSEN-2	6	50	24	25	1,140 2.090	2.0 3.0
			Triangular chutes				
198	TSEN-2	8	50	24	33	2,340	2.7, 3.0, 3.2
			Triangular chutes				

Test Configuration Index (continued)

Configuration	Nozzle identification number	Ejector identification number	Flow conditions: Total temperature (°F)	Flow conditions: Pressure ratio
199	1	1	2,540	2.3, 2.5, 2.7
200	1	2	2,540	2.0, 2.3, 2.7, 3.0
201	1	4	2,540	2.0, 2.3, 2.7, 3.0, 3.3
202	1	6	2,540	2.0, 2.2, 2.7, 3.0
203	1	8 Ejector wall hard-lined	2,540	2.0, 2.2, 2.7, 3.0
204	1	8 Divergent-lined extension on ejector	2,540	2.0, 2.2, 2.7, 3.0
205	1	8 Ejector wall hard-lined; divergent-lined extension on ejector	2,540	2.0, 2.2, 2.7, 3.0
206	1	6 Ejector wall hard-lined; blow-in doors	2,540	2.0, 2.2, 2.7, 3.0
207	1	E	2,540	2.7, 3.0, 3.3
208	1	G	2,540	2.0, 2.2, 2.7, 3.0, 3.3
209	3	6	2,540	2.0, 2.7, 3.0
210	4 Ejector wall hard-lined	5	2,540	2.0, 2.7, 3.0
211	4	6	2,540	2.0, 2.2, 2.7, 3.0
212	4 Ejector wall hard-lined		2,540	2.0, 2.2, 2.7, 3.0
213	6 Ejector wall hard-lined	8	2,540	2.0, 2.2, 2.7, 3.0
214	1	8	2,540	2.0, 2.2, 2.7, 3.0

A.3 FULL-SCALE NOZZLE NOISE AND PERFORMANCE TESTS IN 1966

Facility: North end of Boeing Field, Seattle
YJ75-P-3 afterburning turbojet engine

Acoustic Data Reference:
(1) Coordination sheet 733-EDAS-60, "Status Report—J75 Suppressor Test Program," R. B. Tate, September 9, 1966
(2) Coordination sheet 733-EDAS-65, "Acoustic Data Analysis—J75 Suppressor Tests," R. B. Tate and J. Zurcher. November 21, 1966
(3) W. Klang, *Engine Noise Suppression Program—SST*, T6A-10341-3, The Boeing Company, October 1966

Performance Data Reference:
(1) Ibid
(2) Boeing document D6A-11065-1, "Exhaust System Performance Incorporating the Chuted Ejector Noise Suppressor for the 2707 (SST) Prototype Airplane," September, 1967

Performance Data Reference: Ibid

A.3.1 Test Hardware

A.3.1.1 Nozzles

Designation	Description
RC	Round convergent nozzle with conical center plug; $A_T = 527$ in.^{2}
16-pt star	16-point star-shaped convergent nozzle, 12% penetration of the primary flow; $A_T = 538$ in.^{2} Lab dwg SK11-029347
4 lobes	Conical section fitted with four lobes with parallel sides and rounded extremities. Lobes positioned 90° apart. The ratio of the outer diameter of the lobes to the diameter of the conical section = 2:1, providing 50% lobe penetration of the flow; $A_T = 538$ in.^{2} Lab dwg SK11-036760
RC (AB)	Round convergent nozzle; $D_T = 32.4$ in., $A_T = 823$ in.^{2} Reference nozzle used for afterburning engine conditions. Lab dwg SK11-036762
4 lobes (AB)	Similar to four-lobe nozzle described above except $A_T = 823$ in.^{2} Used for afterburning engine conditions. Lab dwg SK11-036765

A.3.1.2 Ejectors

Designation	Description
	Note: Ejector configurations tested had chutes 2.6 and 3.6 in. wide or scoops 2.6 in. wide. Jet penetration by the chutes or scoops varied between 30% and 50%.
1	Bellmouth entrance followed by a divergent conical section. The ratio of the ejector throat diameter to the exit diameter of the primary nozzle, RC. was 1.2:1, and the ratio of the ejector exit diameter to that of the throat was 1.1:1. Ejector positioned axially so its throat was 5 in. aft of primary nozzle exit plane. This ejector was used for non after-burning engine settings. Lab dwg SK11-036761.
2	A scaled-up version of ejector 1. It was used with the larger area nozzles for afterburning engine conditions. Lab dwg SK11-036764.

A.3.2 Test Configuration Index

Configuration	Nozzle	Ejector	Chutes		Scoops		Flow penetration (%)
			Quantity	Width (in.)	Quantity	Width (in.)	
1	RC	No					
2	4 lobes	No					
3	16-pt star	No					
4	16-pt star	Yes					
5	16-pt star	Yes			8	2.6	30
6	16-pt star	Yes			8	2.6	50
7	16-pt star	Yes			4	2.6	50
8	16-pt star	Yes	8	2.6			50
9	16-pt star	Yes	8	2.6			30
10	16-pt star	Yes	4	2.6			50
11	RC	Yes					
12	RC	Yes					
13	RC	Yes			8	2.6	30
14A	4 lobes (AB)	No					

Configuration	Nozzle	Ejector	Quantity		Scoops		Flow penetration (%)
			Quantity	Width (in.)	Chutes	Width (in.)	
15A	RC (AB)	No					
16A	RC (AB)	Yes					
17A	RC (AB)	Yes	8	3.6			30
18A	RC (AB)	Yes	8	3.6			44
19A	RC (AB)	Yes			8	2.6	37

A.3.3 Primary Flow Test Conditions

A.3.3.1 Configurations 1 Through 13

Pressure ratio ($P_{T7}/P_{T_{AMB}}$)	Total temperature (T_{T7})	Jet velocity (ideal)
2.5	1,020°F	2,050 fps

A.3.3.2 Configurations 14A Through 19A

Pressure ratio ($P_{T10}/P_{T_{AMB}}$)	Total temperature (T_{T10})	Jet velocity (ideal)
2.2*	2,880°F*	2,900 fps

*Values calculated from measured engine parameters.

A.4 FULL-SCALE NOZZLE NOISE AND PERFORMANCE TESTS IN 1967 (PHASE 1)

Facility: Boardman, Oregon (Pad B-1)
YJ75-P-3 afterburning turbojet engine

Acoustic Data Reference: Boeing Test Report T6A10493-2, "Acoustic and Performance Evaluation of a B-2707 Jet Noise Suppressor (SST)," R. D. Cuthbertson and J. V. O'Keefe, August 1967

Performance Data Reference: (1) Ibid
(2) Boeing Test Report T6A10493-1, "Test Report for J-75 Turbojet Engine Noise Suppression Program, EWA 321599," W. Klang, June 1967

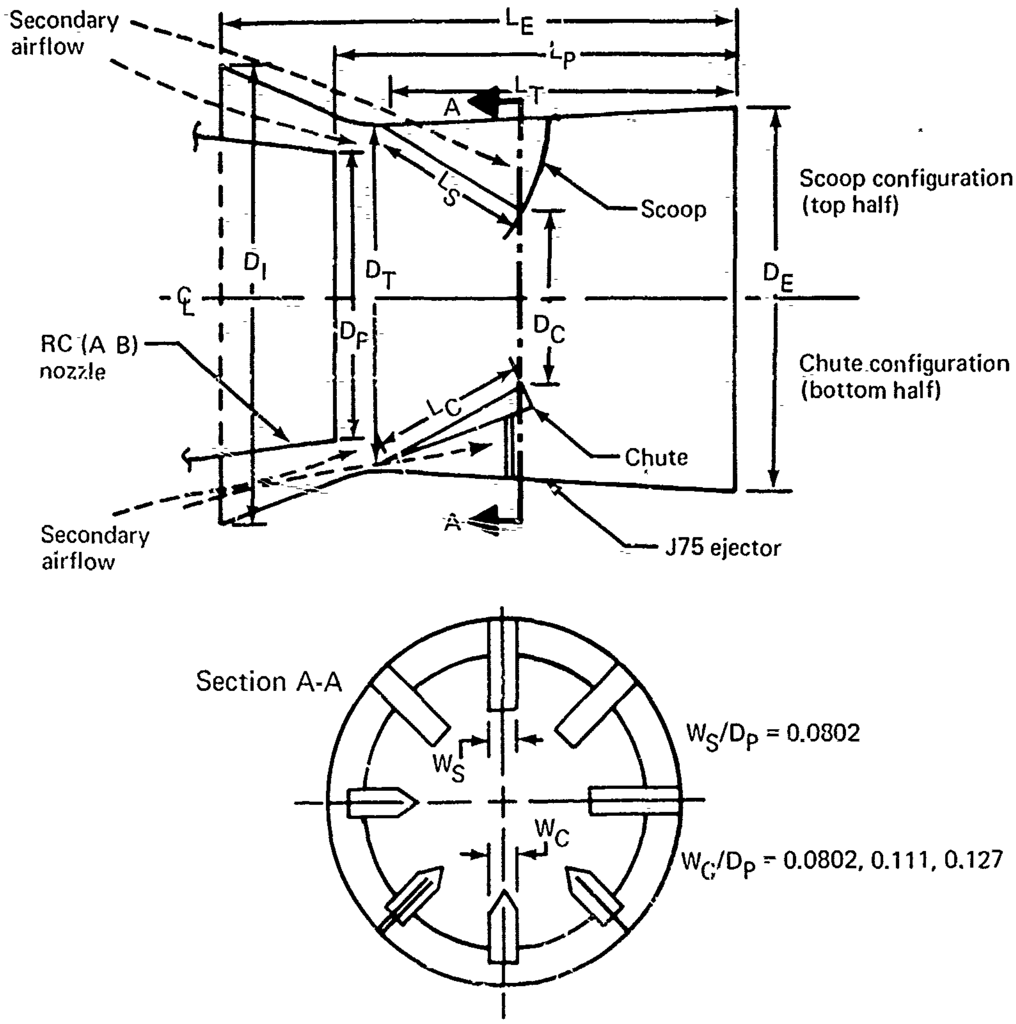
A.4.1 Test Hardware

A.4.1.1 Nozzles

Designation	Description
RC (AB)	Round convergent nozzle; $D_T = 32.4$ in., $A_T = 823$ in.^{2}
4 lobes (AB)	Conical section fitted with four lobes with parallel sides and rounded tops. Lobes positioned 90° apart. The ratio of the outer diameter of the lobes to the diameter of the conical section was 2:1, providing 50% lobe penetration of the flow; $A_T = 823$ in.^{2}

A.4.1.2 Ejectors

Designation	Description
	Note: Ejector configurations tested had chutes 2.6, 3.6, and 4.1 in. wide or scoops 2.6 in. wide to intercept the jet. Flow penetrations tested were 30%, 40%, and 50%.
1	Round ejector; $D_I = 51.7$ in., $D_T = 39.2$ in., $D_E = 43.1$ in., overall length = 61.2 in. (see fig. A-1)



D_P	D_T/D_P	D_E/D_T	D_I/D_P	PEN.	L_T/D_P	L_E/D_P	L_P/D_P	L_C/D_P	L_S/D_P
32.4	1.21	1.10	1.596	30, 40, 50%	1.26	1.889	1.414	0.534	0.534

D_P = Diameter of RC(AB) nozzle
D_T = Ejector throat diameter
D_E = Ejector exit diameter
D_I = Ejector inlet diameter
D_C = Unblocked jet flow diameter
PEN. = 100% x $(D_P - D_C)/D_P$
RC(AB) = Round convergent—afterburner

L_T = Distance, throat to exit
L_E = Overall ejector length
L_P = Distance, nozzle to exit
L_C = Chute length
W_C = Chute width: 2.6, 3.6, 4.1 in.
L_S = Scoop length
W_S = Scoop width: 2.6 in.

FIGURE A-1.—RC(AB) NOZZLE—EJECTOR WITH CHUTES OR SCOOPS (CONFIGURATION FOR YJ75 FULL-SCALE TEST)

A.4.2 Test Configuration Index

Configuration	Primary nozzle	Ejector	Chutes Quantity	Chutes Width (in.)	Scoops Quantity	Scoops Width (in.)	Flow penetration (%)
1	RC (AB)	No					
2	RC (AB)	Yes					
3	RC (AB)	Yes	8	2.6			30
4	RC (AB)	Yes	8	2.6			40
5	RC (AB)	Yes	8	2.6			50
6	RC (AB)	Yes	8	3.6			30
7	RC (AB)	Yes	8	3.6			40
8	RC (AB)	Yes	8	3.6			50
9	RC (AB)	Yes	8	4.1			30
10	RC (AB)	Yes	8	4.1			40
11	RC (AB)	Yes	8	4.1			50
12	RC (AB)	Yes			8	2.6	30
13	RC (AB)	Yes			8	2.6	40
14	RC (AB)	Yes			8	2.6	50
15	RC (AB)	Yes	4	2.6			50
16	RC (AB)	Yes	4	2.6			40
17	4 lobes (AB)	No					

A.4.3 Primary Flow Test Conditions (Each Configuration)

Pressure ratio	Total temperature (°F)	Ideal jet velocity (fps)
1.9	2,910	2,640
2.0	3,080	2,800
2.2	3,190	3,020

A.5 FULL-SCALE NOZZLE NOISE AND PERFORMANCE TESTS IN 1967 (PHASE 2)

Facility: Boardman, Oregon (Pad B-1)
J-75 afterburning turbojet engine

Acoustic Data Reference: Boeing Test Report T6A11034-1, "Large Scale Jet Noise Suppression Tests—Acoustic and Performance Evaluation (Series No. 1)," G. W. Bielak, et al., March 1968

Performance Data Reference: Ibid

A.5.1 Test Hardware

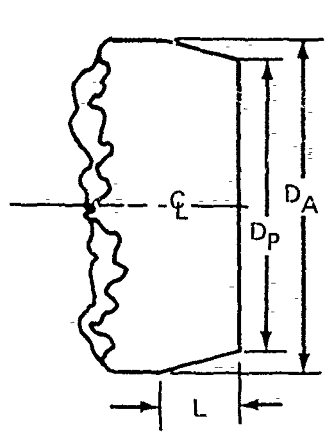
A.5.1.1 Nozzles

Designation	Description
RC (AB)	Round convergent nozzle; D_T = 32.4 in., A_T = 823 in.^{2} (see fig. A-2)
16-pt star (AB)	16-point star-shaped convergent nozzle, 12% penetration of the primary flow; A_T = 823 in.^{2} (see fig. A-2)
4 lobes (AB)	Conical section fitted with four lobes with parallel sides and rounded extremities. Lobes positioned 90° apart. The ratio of the outer diameter of the lobes to the diameter of the conical section was 2:1, providing 50% lobe penetration of the primary flow; A_T = 823 in.^{2} (see fig. A-2)

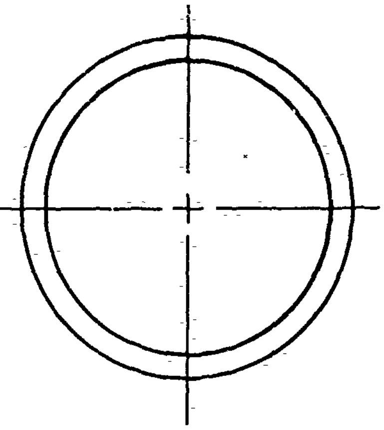
A.5.1.2 Ejectors

Designation	Description
1	Note: Ejector configurations tested had flat chutes with sides, conical chutes, box chutes, and wing chutes. Chute lengths were 17.3 and 17.8 in. Chute flow penetration was 40%. (See figs. A-3 and A-4.)
2	Round (cylindrical) ejector; D_I = 66.1 in., D_T = D_E = 40.2 in., overall length = 69.3 in. (see fig. A-5)
3	Same as ejector 2 except D_T = 48.6 in.

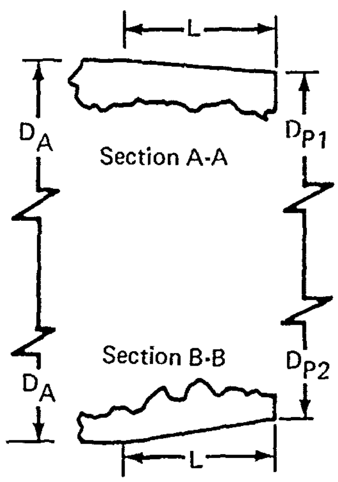
Round convergent nozzle: (ref. dwg SK11-036762)



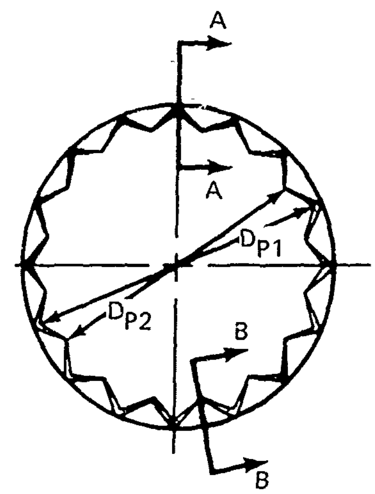
$D_P = 32.4$
$D_A/D_P = 1.12$
$L/D_P = 0.278$



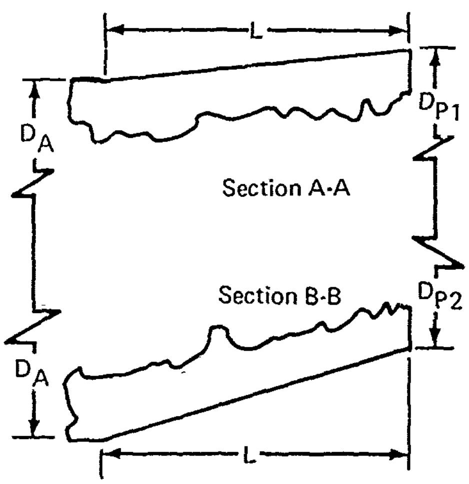
16-pt star nozzle—12% PEN. (ref. dwg SK11-040192):



$D_P = 32.4$ (ref)
$D_{P1}/D_P = 1.07$
$D_{P2}/D_P = 0.941$
$D_A/D_P = 1.12$
$L/D_P = 0.530$



Four-lobe nozzle (ref. dwg SK11-036765):



$D_P = 32.4$ (ref)
$D_{P1}/D_P = 1.34$
$D_{P2}/D_P = 0.670$
$D_A/D_P = 1.12$
$D_L/D_P = 0.401$
$W_L/D_P = 0.940$
$L/D_P = 1.08$

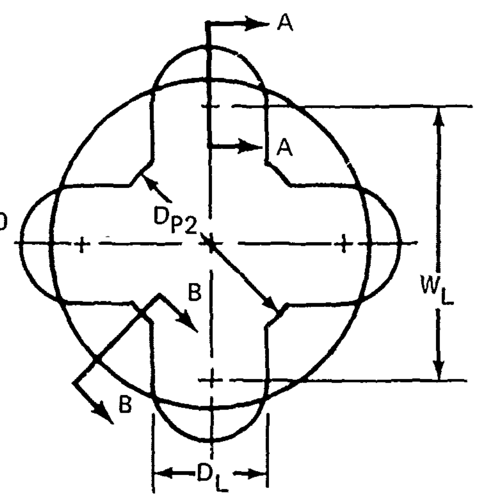
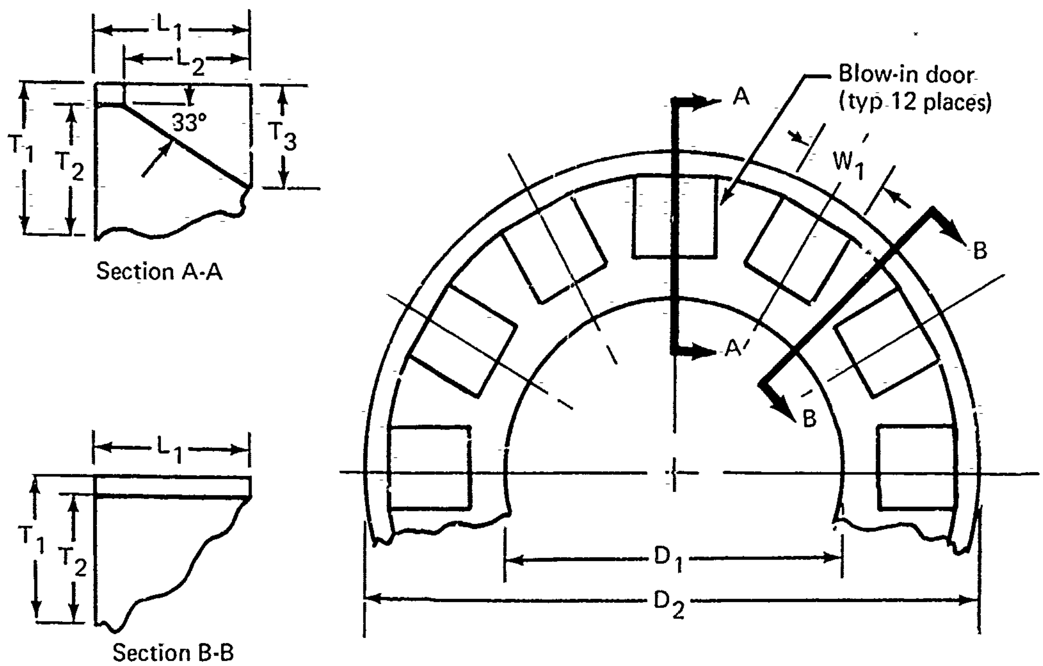


FIGURE A-2.—PRIMARY NOZZLES FOR YJ75 WITH AFTERBURNER (BOARDMAN TESTS)

Blow-in door simulator (ref. dwg SK11-040206):



D_P	T_1/D_P	T_2/D_P	T_3/D_P	L_1/D_P	L_2/D_P	W_1/D_P	D_1/D_P	D_2/D_P
32.4	0.499	0.431	0.356	0.556	0.444	0.273	1.16	2.16

Divergent ejector extension (ref. dwg SK11-040205):

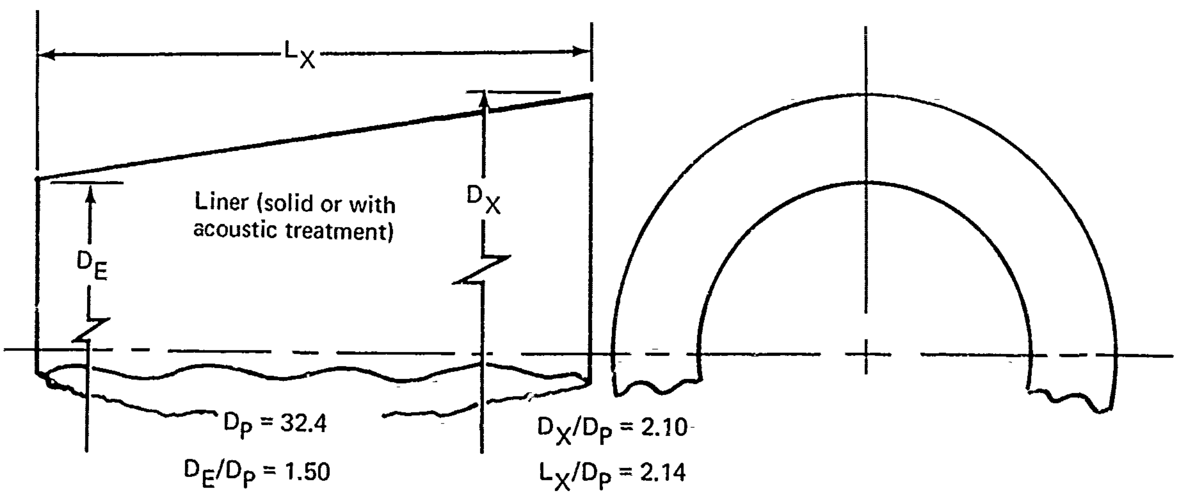
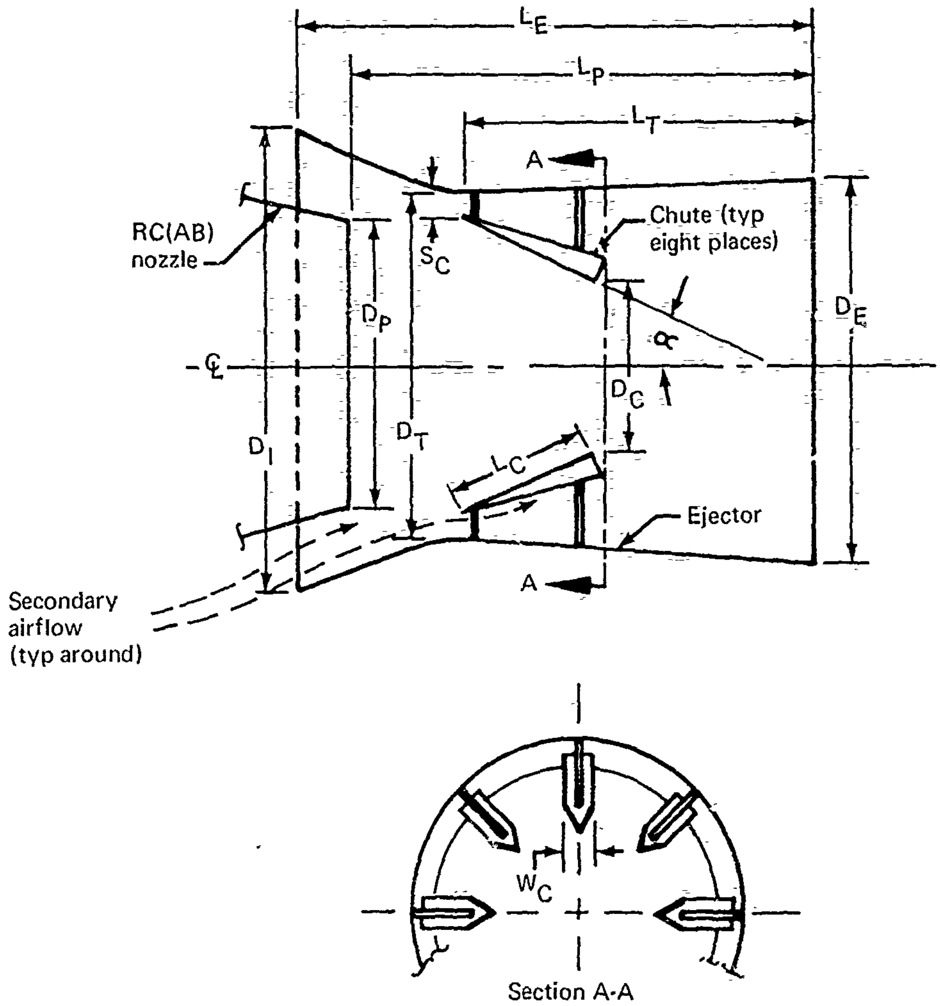


FIGURE A-3.—ATTACHMENTS FOR 1.50 D_E/D_P CYLINDRICAL EJECTOR (BOARDMAN TESTS)

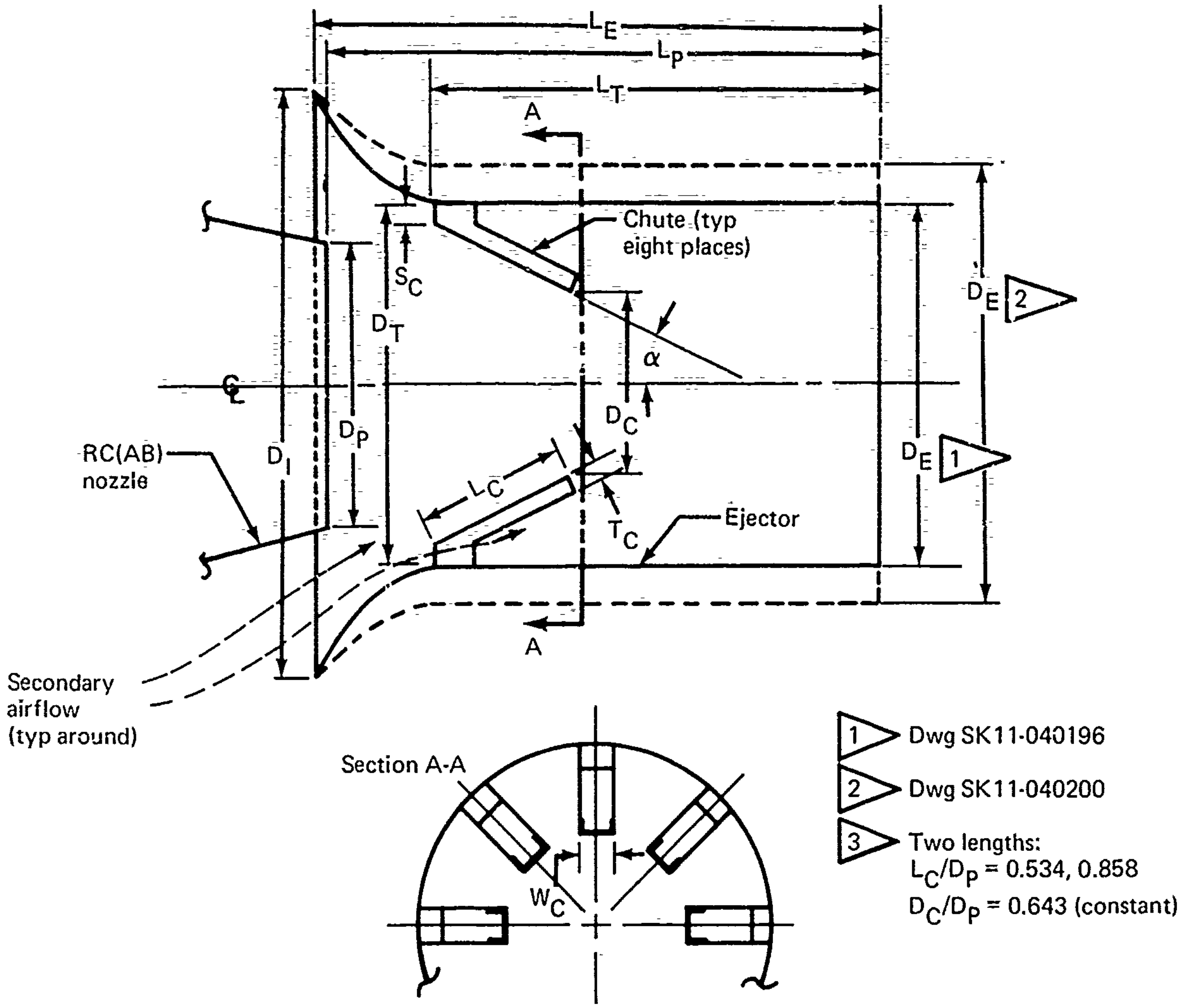


D_P	D_T/D_P	D_E/D_T	D_I/D_P	D_C/D_P	L_T/D_P	L_E/D_P	L_P/D_P	L_C/D_P	W_C/D_P	S_C/D_P
32.4	1.21	1.10	1.60	0.506 0.600 0.700	1.26	1.89	1.70	0.543	0.111 0.127	0.0810

D_P = Diameter of RC(AB) nozzle
D_T = Ejector throat diameter
D_E = Ejector exit diameter
D_I = Ejector inlet diameter
D_C = Unblocked jet flow diameter
L_T = Distance, throat to exit
L_E = Overall ejector length
RC(AB) = Round convergent, afterburner
L_P = Distance, nozzle to exit

L_C = Chute length
W_C = Chute width
S_C = Chute inlet step
α = Chute angle of attack
= 19.0°, 24.8°, 30.5°
PEN. = 100% $(D_P - D_C)/D_P$
= 30%, 40%, 50%

FIGURE A-4.—RC(AB) NOZZLE—EJECTOR WITH CHUTES (CONFIGURATION FOR YJ75 FULL SCALE TEST, DIVERGENT EJECTOR STUDY)



D_P	D_T/D_P	D_E/D_T	D_I/D_P	L_T/D_P	L_E/D_P	L_P/D_P	L_C/D_P	W_C/D_P	T_C/D_P	S_C/D_P	
32.4	1.24	1.00	2.04	1.58	2.14	1.96	3	0.111	0.0555	0.0898	1
32.4	1.50	1.00	2.04	1.58	2.14	1.96	3	0.111	0.0555	0.199	2

D_P = Diameter of RC(AB) nozzle
D_T = Ejector throat diameter
D_E = Ejector exit diameter
D_I = Ejector inlet diameter
D_C = Unblocked jet flow diameter
PEN. = 100% $(D_P - D_C)/D_P \approx 40.0\%$
L_T = Distance, throat to exit
RC(AB) = Round convergent, afterburner

L_E = Overall ejector length
L_P = Distance, nozzle to exit
L_C = Chute length
W_C = Chute width
T_C = Chute thickness
S_C = Chute inlet step
α = Chute angle of attack
= 25.5°, 15.6°

FIGURE A-5.—RC(AB) NOZZLE—EJECTOR WITH CHUTES (CONFIGURATION FOR YF75 FULL-SCALE TEST, CYLINDRICAL EJECTOR STUDY)

A.5.2 Test Configuration Index

Configuration	Primary nozzle	Ejector identification number	Chutes[a]			Remarks[b]
			Type	Quantity	Length (in.)	
1	RC (AB)	2	FWS	8	17.3	
2	RC (AB)	2	Cone	8	17.3	
3	RC (AB)	2	Wing	8	27.8	
4	RC (AB)	2	Box	8	27.8	
5	RC (AB)	2	FWS	8	27.8	
6	RC (AB)	3	Wing	8	27.8	
7	RC (AB)	3	Box	8	27.8	
8	RC (AB)	3	FWS	8	27.8	
9	RC (AB)	2	FWS	8	17.3	$\alpha = 25.5°$
10	RC (AB)	2	FWS	8	27.8	$\alpha = 15.6°$
11	RC (AB)	3	FWS	8	17.3	$\alpha = 25.5°$
12	RC (AB)	3	FWS	8	27.8	$\alpha = 15.6°$
13	RC (AB)	3	FWS	5	17.3	
14	RC (AB)	3	FWS	7	17.3	
15	RC (AB)	3	FWS	8	17.3	
16	RC (AB)	1	Cone	8	17.3	
17	RC (AB)	1	FWS	8	27.8	
18	RC (AB)	3	None			2-D_P extension
19	16-pt star (AB)	3	None			2-D_P extension
20	RC (AB)	3	None			
21	16-pt star	3	FWS	8	17.3	2-D_P extension
22	RC (AB)	3	None			BID added
23	RC (AB)	3	FWS	8	17.3	BID added
24	RC (AB)	3	FWS	8	27.8	BID added
25	RC (AB)	3	FWS	8	27.8	Water injection
26	16-pt star	3	FWS	8	17.3	2-D_P extension
27	RC (AB)	3	FWS	8	17.3	Lined ejector
28	RC (AB)	3	FWS	8	17.3	Lined, 2-D_P ext.
29	4 lobes (AB)	–				
30	4 lobes (AB)	3	None			
31	4 lobes (AB)	3	FWS	4	17.3	
32	4 lobes (AB)	3	FWS	4	17.3	60% penetration
33	16-pt star (AB)	–				

[a] 1) All chutes were 3.6 in. wide.
2) Chute penetration of the jet was 40% unless otherwise noted.

[b] α = chute angle of attack
FWS = flat chute with sides
2-Dp extension = overall ejector length equal to 134 in.
BID = blow-in-door simulation added to ejector

A.5.3 Primary Flow Test Conditions (Each Configuration)

Pressure ratio ($P_{T10}/P_{T_{AMB}}$)	Total temperature (°F) (T_{T10})	Ideal jet velocity (fps)
1.84	2,900	2,570
2.02	3,100	2,800
2.20	3,200	3,020

A.6 FULL-SCALE NOZZLE NOISE AND PERFORMANCE TESTS IN 1967 (PHASE 3)

Facility: Boardman, Oregon (Pad B-1)
YJ-75 afterburning turbojet engine

Acoustic Data Reference: Boeing Test Report T6A11034-2, "Large Scale Jet Noise Suppression Tests—Acoustic and Performance Evaluation (Series No. 2)," G. W. Bielak, et al., May 1968

Performance Data Reference: Ibid

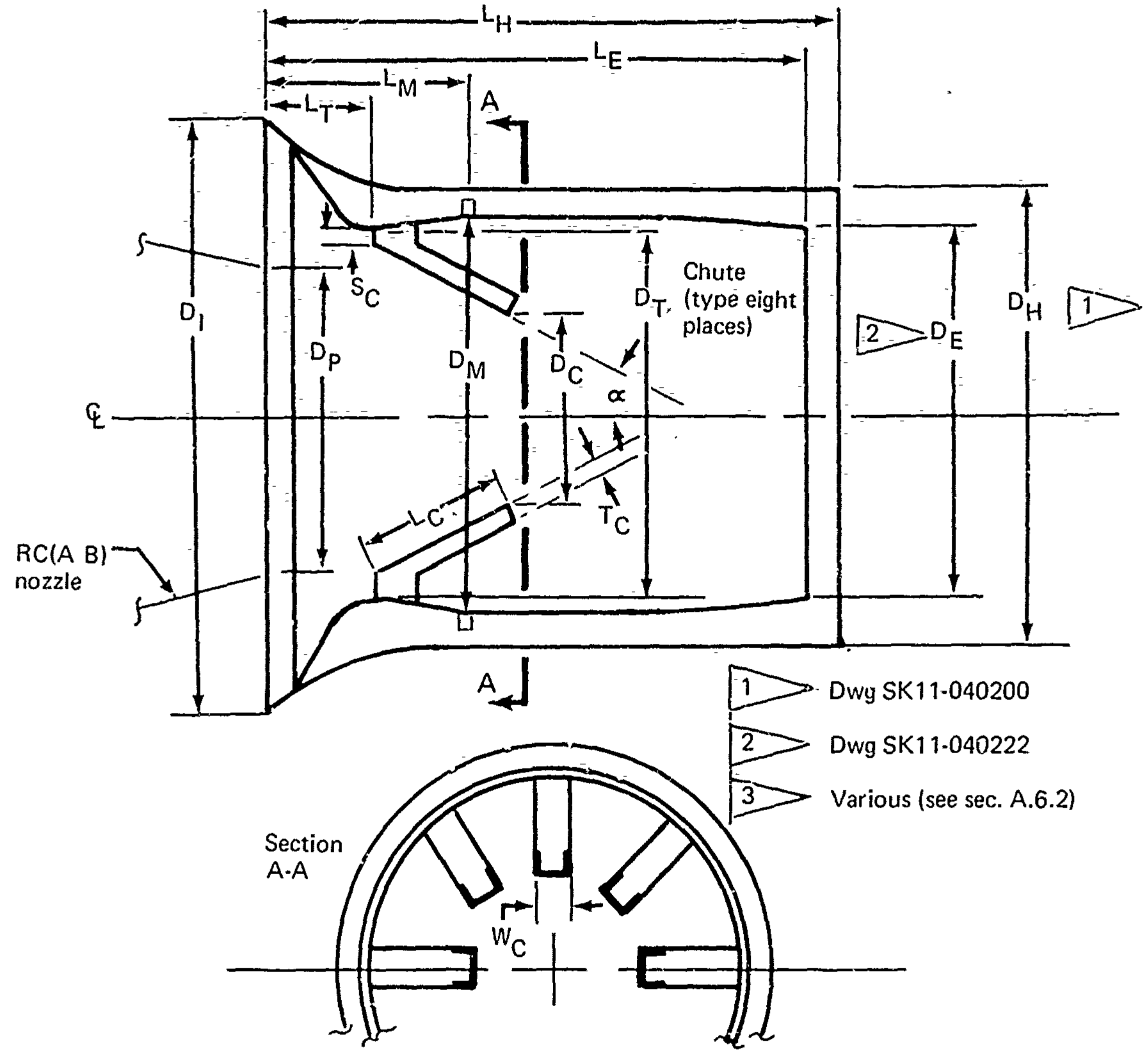
A.6.1 Test Hardware

A.6.1.1 Nozzles

Designation	Description
RC (AB)	Round convergent nozzle; D_T = 32.4 in., A_T = 823 in.^{2}

A.6.1.2 Ejectors

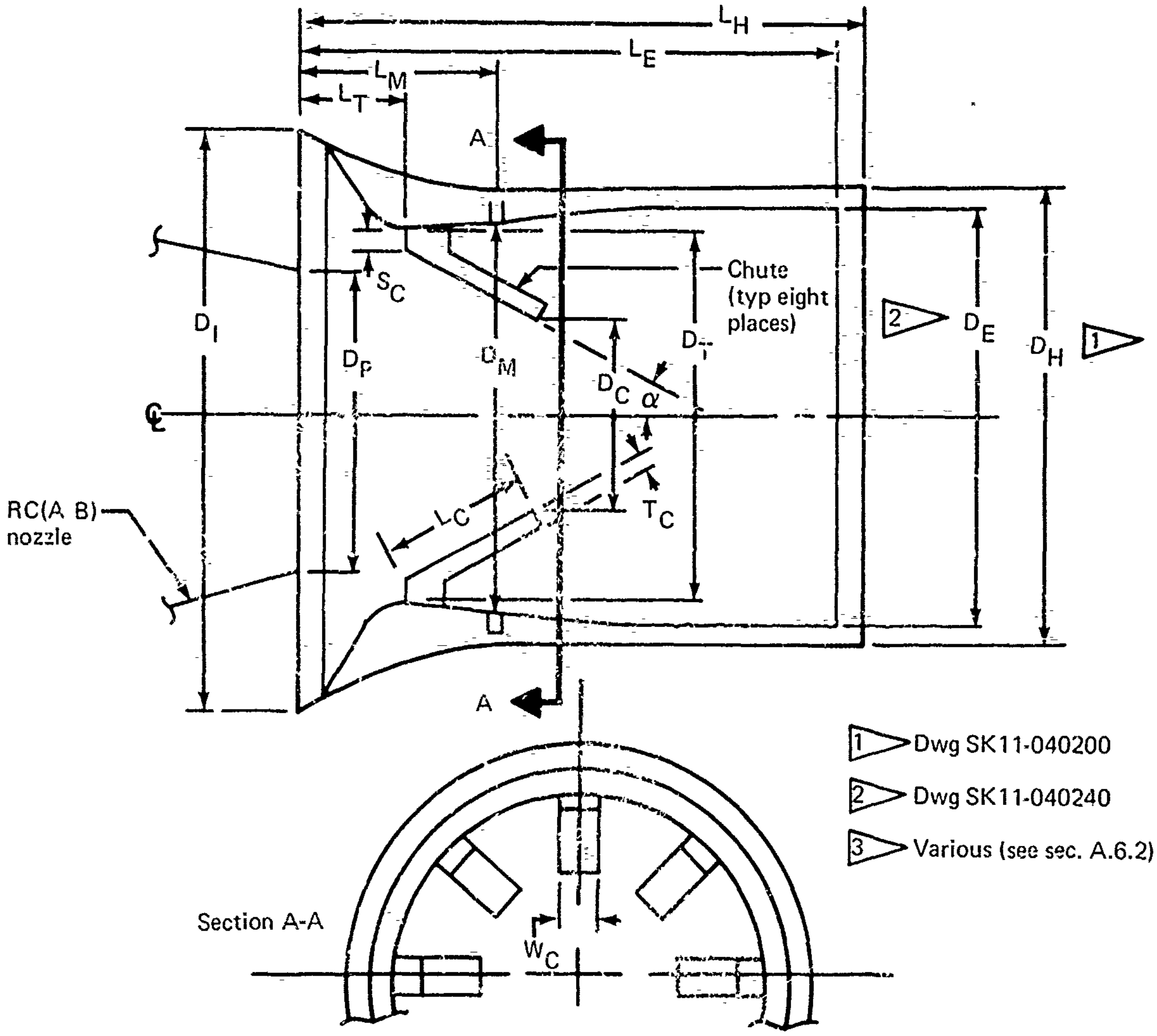
Designation	Description
	Note: Ejector configurations tested had 3.6-in. wide flat chutes with sides (FWS) or water-injection-type chutes (WIT). Chute lengths were 13.0, 17.3, 20.25, 21.0, and 27.8 in. Blow-in-door hardware simulation was added to both ejectors for some tests.
E1	Contoured ejector with the diameter of the throat equal to the diameter of the exit. Ejector entrance diameter (D_I) = 66.1 in., throat diameter (D_T) = 40.2 .n., exit diameter (D_E) = 40.2 in. (see fig. A-6)
E2	Contoured ejector with the diameter of the exit 1.15 times larger than the throat (D_E = 1.15 D_T); D_I = 66.1 in., D_T = 40.2 in., D_E = 46.7 in. (see fig. A-7)



D_P	D_I/D_P	D_T/D_P	D_M/D_P	D_M/D_T	D_E/D_P	D_E/D_T	D_H/D_P	D_C/D_P
32.40	2.04	1.24	1.35	1.09	1.24	1.00	1.50	3

L_T/D_P	L_M/D_P	L_E/D_P	L_H/D_P	L_C/D_P	T_C/D_P	W_C/D_P	S_C/D_P	α
0.47	0.75	1.89	2.07	3	0.0555	0.111	0.0772	3

FIGURE A-6.—RC(A B) NOZZLE—E1 EJECTOR CONFIGURATION FOR YJ75 FULL-SCALE TEST, CHUTE AT THROAT



D_P	D_I/D_P	D_T/D_P	D_M/D_P	D_M/D_T	D_E/D_P	D_E/D_T	D_H/D_P	D_C/D_P
32.4	2.04	1.24	1.35	1.09	1.44	1.15	1.50	3

L_T/D_P	L_M/D_P	L_E/D_P	L_H/D_P	L_C/D_P	T_C/D_P	W_C/D_P	S_C/D_P	α
0.47	0.75	1.89	2.07	3	0.0555	0.111	0.0772	3

FIGURE A-7.—RC(AB) NOZZLE—E2 EJECTOR CONFIGURATION FOR YJ75 FULL-SCALE TEST, CHUTES AT THROAT

A.6.2 Test Configuration Index

Configuration	Primary nozzle	Ejector	Chutes				Remarks[a]
			Type	Quantity	Length (in.)	Penetration (%)	
1	RC (AB)	E1	FWS	8	13	20	$\alpha = 22°$
2	RC (AB)	E1	FWS	8	13	38	$\alpha = 36°$
3	RC (AB)	E1	FWS	8	13	38	BID added
4	RC (AB)	E1	FWS	8	17.3	35	$\alpha = 24°$
5	RC (AB)	E1	FWS	8	17.3	35	BID added
6	RC (AB)	E2	FWS	8	17.3	35	BID added
7	RC (AB)	E1	FWS	8	21.0	35	$\alpha = 20°$
8	RC (AB)	E1	WIT	8	27.8	37	$\alpha = 16°$
9	RC (AB)	E2	WIT	8	27.8	37	BID added
10	RC (AB)	E1	FWS	8	27.8	37	$\alpha = 16°$
11[b]	RC (AB)	E2	FWS	8	20.2	41	$\alpha = 30°$ and BID
12[b]	RC (AB)	E2	FWS	8	20.2	38	$\alpha = 38°$ and BID
13[b]	RC (AB)	E2	FWS	8	20.2	30	$\alpha = 29°$ and BID
14[b]	RC (AB)	E2	FWS	8	20.2	40	$\alpha = 35°$ and BID
15[b]	RC (AB)	E2	FWS	6	20.2	40	$\alpha = 35°$ and BID
16	RC (AB)						Reference

[a] α = chute angle of attack
FWS = flat chute with sides
BID = blow-in-door simulation hardware
WIT = water-injection-type chutes

[b] Chutes installed forward of ejector throat. All other runs with chutes at ejector throat.

A.6.3 Primary Flow Test Conditions*

Pressure ratio ($P_{T10}/P_{T_{AMB}}$)	Total temperature (°F) (T_{T10})	Ideal jet velocity (fps)
1.93	3,010	2,700
2.11	3,165	2,900
2.28	3,220	3,100

*Each configuration tested at the three sets of conditions.

APPENDIX B
SST 12-20 PNdB SUPPRESSION PROGRAM

This appendix lists most noise suppression hardware tested during the SST high-noise-suppression (12-20 PNdB) program. The test configurations and upstream flow conditions are included as well as available test references.

B.1 MODEL-SCALE (1/8TH) NOZZLE NOISE TESTS IN 1967

Facility: Boeing Annex D, Seattle

Acoustic Data Reference: Boeing Test Report T6A11488-1, "SST High Jet Noise Suppression Program Acoustic Results, Boeing Annex D, Scale Model Nozzle Facility (1967)," June 1969

Performance Data Reference: (1) Boeing Test Report T6A10814-1, "Thrust Performance of a Pure Annulus and Multi-Tube Annular Sound Suppression Concept"
(2) Boeing Document D6A-12118-1 (Informal), "Multi-Spoke Suppressor Nozzle Characteristics—Volume I—Parametric Thrust Performance"

B.1.1 Test Hardware

B.1.1.1 Nozzles

Designation	Description
C-6	Round convergent nozzle with short conical plug equivalent to 1:8 scale JT3C-6 turbojet engine nozzle; D_T = 3.10 in., A_T = 7.07 in.^{2}
PW P1-S1	Round convergent nozzle; D_T = 3.8 in., A_T = 11.34 in.^{2}
PW-S1	Round convergent secondary flow nozzle; D_T = 6.08 in., A_T = 29.2 in.^{2}
HM-J75	Round convergent nozzle; D_T = 4.1 in., A_T = 13.2 in.^{2}
HM-P-0	Convergent annular nozzle; AR = 1.6 A_T = 6.472 in.^{2}
HM-P-1	Plain annular nozzle with -45° exit cant angle (inward); AR = 3.5, A_T = 7.07 in.^{2}
HM-P-2	Plain annular nozzle with -30° exit cant angle (inward); AR = 3.5, A_T = 7.07 in.^{2}
HM-P-3	Plain annular nozzle with -15° exit cant angle (inward); AR = 3.5, A_T = 7.07 in.^{2}
HM-P-4	Plain annular nozzle with 0° exit cant angle (coplanar); AR = 3.5, A_T = 7.07 in.^{2}

Designation	Description
HM-P-5	Plain annular nozzle with 15° exit cant angle (outward); AR = 3.5, A_T = 7.07 in.^{2}
HM-P-6	225-tube annular array with 15° exit cant angle (inward); AR = 7.4, A_T = 7.07 in.^{2}, 0-in. tube length
HM-P-7	225-tube annular array with -15° exit cant angle (inward); AR = 7.4, A_T = 7.07 in.^{2}, 0.75-in. tube length
HM-P-8	225-tube annular array with -15° exit cant angle (inward); AR = 7.4, A_T = 7.07 in.^{2}, 1.5-in. tube length
HM-P-9	225-tube annular array with -15° exit cant angle
HM-AP-6	Six radial arms with 20 parallel slots per arm; AR = 8.28, A_T = 13.2 in.^{2}, 0 exit cant angle
HM-AP-9	24 spokes with 95% flow penetration; AR = 1.9, A_T = 13.2 in.^{2}, 17.5 exit cant angle (outward)
HM-AP-12	Plain annular nozzle with 0° exit cant angle; AR = 4.0, A_T = 13.2 in.^{2}
HM-AP-15	Six spokes with 50% flow penetration; AR = 1.6, A_T = 13.2 in.^{2}
HM-AP-16	37 equally spaced RC tubes, hexagonal array; AR = 3.33, A_T = 13.2 in.^{2}. 4.6-in. tube length
HM-AP-18	37 equally spaced tubes with 12 spoke ends each, hexagonal array; AR = 4.65, A_T = 13.2 in.^{2}, 7-in. tube length
HM-AP-18a	37 equally spaced tubes with 12 spoke ends each, hexagonal array; AR = 8.0, A_T = 13.2 in.^{2}, 7-in. tube length
HM-AP-22	12 spokes with 70% flow penetration; AR = 1.4, A_T = 13.2 in.^{2}, 17.5 exit cant angle (outward)
HM-AP-23	Seven tubes for tertiary air surrounded by round primary flow nozzle AR = 1.8, A_T = 13.2 in.^{2}
HM-AP-24	Five parallel slots with 19.5 slot aspect ratio; AR = 3.0, A_T = 13.2 in.^{2}, 10.8-in. element length
HM-AP-28	24 spokes with 92.5% flow penetration; AR = 6.0, A_T = 13.2 in.^{2}
HM-AP-32	24 spokes with 90% flow penetration; AR = 4.0, A_T = 13.2 in.^{2}

Designation	Description
HM-AP-33	36 spokes with 90% flow penetration; AR = 4.0, A_T = 13.2 in.^{2}
HM-AP-37	37 equally spaced RC tubes, hexagonal array; AR = 4.65, A_T = 13.2 in.^{2}, 7-in. tube length
HM-AP-38	37 equally spaced RC tubes, hexagonal array; AR = 8.0, A_T = 13.2 in.^{2}, 7-in. tube length
HM-AP-39	37 equally spaced RC tubes, hexagonal array; AR = 4.0, A_T = 13.2 in.^{2}, 7-in. tube length
HM-AP-40	37 equally spaced tubes with 12 spoke ends each, hexagonal array; AR = 3.33, A_T = 13.2 in.^{2}, 7-in. tube length
HM-AP-41	37 equally spaced tubes with 12 spoke ends each, hexagonal array; AR = 4.0, A_T = 13.2 in.^{2}, 7-in. tube length
HM-AP-42	37 equally spaced tubes with 12 spoke ends each, hexagonal array; AR = 5.2, A_T = 13.2 in.^{2}, 7-in. tube length
HM-AP-43	37 equally spaced RC tubes, hexagonal array; AR = 3.33, A_T = 13.2 in.^{2}, 7-in. tube length
HM-AP-44	37 equally spaced RC tubes, hexagonal array; AR = 5.2, A_T = 13.2 in.^{2}, 7-in. tube length
MPP 152	21 RC tubes (three sizes); AR = 2.4, A_T = 6.48 in.^{2}
MPP 452	21-tube nozzle (10 tubes with six spoke ends); AR = 2.6. A_T = 6.5 in.^{2}
MPP 130-20	16 spokes with 70% flow penetration; AR = 2.25, A_T = 5.8 in.^{2}, 20° exit cant angle (outward)
MAE 4A	12 spokes with conical center plug; AR = 2.9, A_T = 6.7 in.^{2}
MAE 53-18	24 spokes and conical center plug; AR = 2.1, A_T = 5.9 in.^{2}, 18° exit cant angle (outward)
MAE 203-3	20 spokes with 80% flow penetration; AR = 2.2, A_T = 3.03 in.^{2}

B.1.1.2 Ejectors

Designation	Description
HM-AP-22	Round cross section with inlet diameter (D_I) = 7.5 in., throat diameter (D_T) = 4.73 in., exit diameter (D_E) = 6.50 in.; inlet-to-throat distance = 2.04 in., total length = 7.55 in.; 12 tapered box chutes 2.5 in. long were installed to intercept the jet within the ejector.
J75 E-9	Round cross section; D_I = 7.3 in., D_T = 6.35 in., D_E = 6.35 in., distance from inlet to throat = 2.98 in., total length = 9.1 in. Uses flat chutes with sides, 3.5 in. long and 0.5 in. wide
HM-AP-12-1	Cylindrical with bellmouth inlet; D_T = 10.5 in., total length = 7.05 in. Uses flat chutes with sides
HM-AP-12-2	Same as HM-AP-12-1 except D_T = 10.78 in.
HM-AP-12-3	Same as HM-AP-12-1 except D_T = 11.39 in.
HM-AP-12-4	Same as HM-AP-12-3 except total length = 14.1 in.
HM-AP-32	Cylindrical; D_T = 8.96 in., total length = 6.4 in. Lined with 1-in. fiberglass blanket

B.1.2 Test Configuration Index

Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio	Noise report reference
1	C-6		60	2.07, 3.11	
			1,100	2.2, 2.6, 3.0	
			1,100	1.8, 3.2, 3.5	
			1,000	2.485, 1.8, 2.2	
			1,000	2.6, 3.0, 3.4	
			1,500	1.8, 2.2, 2.6	
			1,500	3.0, 3.4	
2	PW P1-S1		60	1.6, 2.0	
			500	2.7	
			900	2.7	
			1,488	2.6	
			1,920	2.4	
			2,200	2.7, 3.0	
3	PW S1		Same as Configuration No. 1		
4	HM-J75		60	1.8, 2.2, 2.6, 3.0, 3.2	
			900	1.8, 2.2, 2.6, 3.0, 3.2	
			1,000	1.8, 2.2, 2.6, 3.0, 3.2, 3.4	
			1,500	1.8, 2.2, 2.6, 3.0, 3.2, 3.4	
			2,000	1.8, 2.2, 2.6, 3.0, 3.2, 3.4	
			2,500	1.8, 2.2, 2.6, 3.0, 3.2	
			500	1.117, 1.275, 1.524, 1.892, 2.483, 3.19	
			700	1.117, 1.275, 1.524, 1.892, 2,483, 3.19	
			800	1.117, 1.275, 1.524, 1.892, 2.483, 3.19	
			2,000	1.117, 1.275, 1.524, 1.892, 2,483, 3.19	
			2,300	1.117, 1.275, 1.524, 1.892, 2,483, 3.19	
			60	1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2	

Test Configuration Index (continued)

Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio	Noise report reference
4 (cont.)	HM-J75		500	1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2	
			800	1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2	
			1,000	1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2	
			1,400	1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2	
			1,700	1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2	
			2,000	1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2	
			2,300	1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2	
			2,600	1.1, 1.2, 1.5, 1.8, 2.4, 3.1, 4.2	
5	HM-P-0		60	2.07, 3.11, 2.2, 3.4	B1
6	HM-P-1		60	2.2, 3.4	B1
7	HM-P-2		60	2.2, 3.4	B1
8	HM-P-3		60	2.2, 3.4	B1
9	HM-P-4		60	2.2, 3.4	B1
10	HM-P-5		60	2.2, 3.4	B1
11	HM-P-6		60	2.07, 3.11	B1
12	HM-P-7		60	2.07, 3.11	B1
13	HM-P-8		60	2.07, 3.11	B1
14	HM-P-9		60	2.07, 3.11	B1
15	HM-AP-6		60	1.8, 2.2, 2.6, 3.0, 3.2	B2
			1,000	1.8, 2.2, 2.6, 3.0, 3.2	
			1,500	1.8, 2.2, 2.6, 3.0, 3.2	
			2,000	2.2, 2.6, 3.0, 3.2	
16	HM-AP-9		60	1.8, 2.2, 2.6, 3.0, 3.2	B2, B3
			800	1.8, 2.2, 2.6, 3.0, 3.2	
			1,000	1.8, 2.2, 2.6, 3.0, 3.2	
			1,500	1.8, 2.2, 2.6, 3.0, 3.2	
			2,000	1.8, 2.2, 2.6, 3.0, 3.2	

Test Configuration Index (continued)

Configuration	Nozzle	Ejector	Total temperature (°F)		Noise report reference
17	HM-AP-12		1,500	1.8, 2.2, 2.6, 3.0, 3.2	B4, B5, B6
18	HM-AP-12	HM-AP-12-3	1,500	1.8, 2.2, 2.6, 3.0, 3.2	B4, B6
19	HM-AP-12	HM-AP-12-3 with 8 chutes	1,500	1.8, 2.2, 2.6, 3.0, 3.2	B4, B6
20	HM-AP-12 with centerbody		1,500	1.8, 2.2, 2.6, 3.0, 3.2	B4, B6
21	HM-AP-12 with centerbody	HM-AP-12-3 with 8 chutes	1,500	1.8, 2.2, 2.6, 3.0, 3.2	B4, B6
22	HM-AP-12 with centerbody	HM-AP-12-4 with 8 chutes	1,500	1.8, 2.2, 2.6, 3.0, 3.2	B4, B6
23	HM-AP-12 with centerbody	HM-AP-12-3	1,500	1.8, 2.2, 2.6, 3.0, 3.2	B4, B6
24	HM-AP-12 with centerbody	HM-AP-12-1 with 8 chutes	1,500	1.8, 2.2, 2.6, 3.0, 3.2	B4, B6
25	HM-AP-12 with centerbody	HM-AP-12-2 with 8 chutes	1,500	1.8, 2.2, 2.6, 3.0, 3.2	B4, B6
26	HM-AP-15		60	1.117, 1.275, 1.524, 1.892, 2.483, 3.19, 4.25	B7
			500	1.117, 1.275, 1.524, 1.892, 2.483, 3.19, 4.25	
			800	1.117, 1.275, 1.524, 1.892, 2.483, 3.19, 4.25	
			1,000	1.117, 1.275, 1.524, 1.892, 2,483, 3.19, 4.25	
			1,400	1.117, 1.275, 1.524, 1.892, 2.483, 3.19, 4.25	
			1,700	1.117, 1.275, 1.524, 1.892, 2.483, 3.19, 4.25	
			2,000	1.117, 1.275, 1.524, 1.892, 2.483, 3.19, 4.25	

Test Configuration Index (continued)

Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio	Noise report reference
26 (cont.)	HM-AP-15		2,300	1.117, 1.275, 1.524, 1.892, 2.483, 3.19, 4.25	B7
			2,600	1.117, 1.275, 1.524, 1.892, 2.483, 3.19, 4.25	
			2,900	1.117, 1.275, 1.524, 1.892, 2.483, 3.19, 4.25	
27	HM-AP-16		900	1.8, 2.2, 2.6, 3.0, 3.2	B8, B3
			1,000	1.8, 2.2, 2.6, 3.0, 3.2	
			1,500	1.8, 2.2, 2.6, 3.0, 3.2	
28	HM-AP-18		900	1.8, 2.2, 2.6, 3.0, 3.2	B8, B9, B10
			1,000	1.8, 2.2, 2.6, 3.0, 3.2	
			1,500	1.8, 2.2, 2.6, 3.0, 3.2	
			500	1.275, 1.524, 1.892, 2.483, 3.19	
			700	1.275, 1.524, 1.892, 2.483, 3.19	
29	HM-AP-18a		1,000	1.8, 2.2, 2.6, 3.0, 3.2	B9
			1,500	1.8, 2.2, 2.6, 3.0	
30	HM-AP-22		1,500	1.8, 2.2, 2.6, 3.0, 3.2	B11
31	HM-AP-22	HM-AP-22 with 8 chutes	1,500	1.8, 2.2, 2.6, 3.0, 3.2	B11
32	HM-AP-22	J75-E9 with 8 chutes	1,000	3.0	B11
			1,500	3.0	
33	HM-AP-23		1,500	1.8, 2.6, 3.0, 3.4	B12
			2,000	1.8, 2.6, 3.0, 3.4	
34	HM-AP-24		1,500	1.8, 2.6, 3.0	B13, B14, B15
35	HM-AP-28		1,000	1.8, 2.2, 2.6, 3.0	B16
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
36	HM-AP-32		1,000	1.8, 2.2, 2.6, 3.0, 3.4	B17
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
			2,000	2.6, 3.0, 3.4	

Test Configuration Index (continued)

Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio	Noise report reference
37	HM-AP-32	HM-AP-32	1,000 1,500	1.8, 2.2, 2.6, 3.0, 3.4 1.8, 2.2, 2.6, 3.0, 3.4	B17
38	HM-AP-33		1,500	1.8, 2.2. 2.6, 3.0	None
39	HM-AP-37		1,500	1.8, 2.6, 3.0	B3, B18
40	HM-AP-38		1,500	1.8, 2.6, 3.0	B3
41	HM-AP-39		1,500	1.8, 2.6, 3.0	B3
42	HM-AP-40		1,500	1.8, 2.6, 3.0	B9
43	HM-AP-41		1,000 1,500	1.8, 2.2, 2.6, 3.0 1.8, 2.6, 3.0	B9, B19
44	HM-AP-42		1,500	2.6, 3.0	B9, B20
45	HM-AP-43				B3
46	HM-AP-44		1,500	1.8, 2.6, 3.0	B3
47	MPP 152		1,100	2.2, 2.6, 3.0	B21, B22
48	MPP 452		1,100	1.8, 2.2, 2.6, 3.0, 3.2; 3.5	B21, B22
49	MPP 130-20		1,100	2.2, 2.6, 3.0	B21
50	MAE 4A		1,100	2.2, 2.6, 3.0	B21
51	MAE 53-18 (no plug)		1,100	2.2, 2.6, 3.0	B21
52	MAE 53-18		1,100	2.2, 2.6, 3.0	B21
53	MAE 203-3		1,100	2.2, 2.6, 3.0	B21

B.2 MODEL-SCALE (1/8TH) NOZZLE NOISE TESTS IN 1968

Facility: Boeing AnnexD, Seattle

Acoustic Data Reference: No formal documentation

Performance Data Reference:
(1) Boeing Document D6A12118-1 (Informal), "Multi-Spoke Suppressor Nozzle Characteristics—Volume I—Parametric Thrust Performance"
(2) Boeing Document D6A11815-1, "Ninety-Six-Tube Jet Noise Suppressor Acoustic Performance Test Data Analysis, Model NSC-82"
(3) Boeing Document T6A1178-1, Test Data Report—Base Pressure Investigation of the NSC-82 Jet Noise Suppressor Nozzle with External Flow," February 1970
(4) Boeing Document D6A11822-1 and -2, "Multi-Tube Suppressor Noise Performance—Vols I and 2," July 1970

B.2.1 Test Hardware

B.2.1.1 Nozzles

Designation	Description
HM-J75	Round convergent nozzle, 1:8 scale of J-75 nozzle; D_T = 4.1 in., A_T = 13.2 in.^{2}
C-6	Round convergent nozzle with short conical plug equivalent to 1:8 scale JT3C-6 turbojet engine nozzle; D_T = 3.10 in., A_T = 7.07 in.^{2}
2.86-in. diameter (standard)	Round convergent nozzle; D_T = 2.86 in., A_T = 6.42 in.^{2}
4.75-in. diameter (standard)	Round convergent nozzle; D_T = 4.75 in., A_T = 17.72 in.^{2}
HM-AP-9	24 spokes with 95% flow penetration; AR = 1.9, A_T = 13.2 in.^{2}, 17.5 exit cant angle (outward)
HM-AP-20	Annulus slot and center plug shaped for coanda effect (flow attachment); AR = 6.5, A_T = 11.4 in.^{2}, 60° exit cant angle (outward)
HM-AP-23	Seven tubes for tertiary air surrounded by round primary flow nozzle; AR = 1.8, A_T = 13.2 in.^{2}
HM-AP-32	24 spokes with 90% flow penetration; AR = 4.0, A_T = 13.2 in.^{2}

Designation	Description
HM-AP-33	36 spokes with 90% flow penetration; AR = 4.0, A_T = 13.2 in.^{2}
HM-AP-36	60 radial slots, annular arrangement, with 0° exit cant angle; AR = 5.0, A_T = 13.2 in.^{2}, some configurations had a center plug
HM-AP-37	37 equally spaced RC tubes, hexagonal array; AR = 4.65, A_T = 13.2 in.^{2}, 7-in. tube length
HM-AP-41	37 equally spaced tubes with 12 spoke ends each, hexagonal array; AR = 4.0, A_T = 13.2 in.^{2}, 7-in. tube length
HM-AP-43	37 equally spaced RC tubes, hexagonal array; AR = 3.33, A_T = 13.2 in.^{2}, 7-in. tube length
HM-AP-46	49 RC tubes arranged in seven tube clusters; AR = 5.2 (cluster AR = 3.0), A_T = 17.5 in.^{2}, 7-in. tube length
HM-AP-47	49 tubes with 12 spoke ends each, arranged in seven tube clusters; AR = 5.2 (cluster AR = 3.0), A_T = 17.5 in.^{2}, 7-in. tube length
HM-AP-48	49 RC tubes arranged in seven tube clusters; AR = 6.5 (cluster AR = 3.0), A_T = 17.5 in.^{2}, 7-in. tube length
HM-AP-49	49 tubes with 12 spoke ends each, arranged in seven tube clusters; AR = 6.5 (cluster AR = 3.0), A_T = 17.5 in.^{2}, 7-in. tube length
HM-AP-50	49 RC tubes arranged in seven tube clusters; AR = 6.5 (cluster AR = 4.0), A_T = 17.5 in.^{2}, 7-in. tube length
HM-AP-51	49 tubes with 12 spoke ends each, arranged in seven tube clusters; AR = 6.5 (cluster AR = 4.0), A_T = 17.5 in.^{2}, 7-in. tube length
HM-AP-52	49 RC tubes arranged in seven tube clusters; AR = 7.8 (cluster AR = 3.0), A_T = 17.5 in.^{2}, 7-in. tube length
HM-AP-53	49 tubes with 12 spoke ends each, arranged in seven tube clusters; AR = 7.8 (cluster AR = 3.0), A_T = 17.5 in.^{2}, 7-in. tube length
HM-AP-56	37 tubes with hexagonal end for tertiary air surrounded by hexagonal-shaped primary flow nozzle; AR = 4.0, A_T = 13.2 in.^{2}
HM-AP-57	12 spokes with 75% flow penetration; AR = 1.86, A_T = 13.2 in.^{2}
HM-AP-79	49 equally spaced RC tubes; AR = 4.0, A_T = 17.5 in.^{2}, 7-in. tube length
HM-AP-80	49 equally spaced tubes with 12 spoke ends each; AR = 4.0, A_T = 17.5 in.^{2}, 7-in. tube length

Designation	Description
HM-AP-81-1	36 RC tubes, rectangular array (6 x 6); AR = 3.45, A_T = 12.8 in.^{2}, 7-in. tube length
HM-AP-81-2	36 RC tubes, rectangular array (6 x 6); AR = 5.4, A_T = 12.8 in.^{2}, 7-in. tube length
HM-AP-82-1	36 RC tubes, rectangular array (4 x 9); AR = 3.4, A_T = 12.8 in.^{2}, 7-in. tube length
HM-AP-82-2	36 RC tubes, rectangular array (4 x 9); AR = 5.4, A_T = 12.8 in.^{2}, 7-in. tube length
MPP 152	21 RC tubes (three sizes); AR = 2.4, A_T = 6.48 in.^{2}
MPP 452	21-tube nozzle (10 outer tubes with six spoke ends); AR = 2.6, A_T = 6.5 in.^{2}
253 tubes	253 round convergent-divergent tubes; AR = 4.0, A_T = 6.43 in.^{2}, 6-in. tube length

B.2.1.2 Ejectors

Designation	Description
HM-AP-43	Tight-fitting ejector, hexagonal cross section, 6 in. long
HM-AP-23	No information available
HM-AP-56	No information available
HM-AP-20	No information available
E1	Cylindrical ejector with 10-in. inside diameter, lined with 1-in. TWF fiberglass; 16.67 in. long
E2	Cylindrical ejector with 10-in. inside diameter (unlined); 16.67 in. long
E3	Cylindrical ejector with 11.67-in. inside diameter (unlined); 33.33 in. long
E4	Cylindrical ejector with 11.67-in. inside diameter, lined with 1-in. TWF fiberglass; 33.33 in. long
E5	Cylindrical, corrugated ejector with 10-in. inside diameter (unlined); 16.67 in. long
E6	Round ejector, divergent from 10-in. inside diameter to 11-in. inside diameter

B.2.2 Test Configuration Index

Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio	Noise report reference
1	HM-J75		1,000	1.4, 1.6, 1.8, 2.2, 2.6, 3.0, 3.2, 3.4	
			1,500	1.4, 1.6, 1.8, 2.2, 2.6, 3.0, 3.2, 3.4	
			540	1.8	
			1,200	2.2	
2	C-6		1,000	1.8, 2.0, 2.2, 2.5, 3.0, 3.4	
			1,500	1.8, 2.6, 3.0, 3.4	
3	2.86-in. diameter (standard)		1,000	1.8, 2.0, 2.2, 2.48, 3.0, 3.4	
4	4.75-in. diameter (standard)		1,000	1.4, 1.8, 2.2	
			1,140	1.8	
			1,500	1.8, 2.6, 3.0	
			1,640	1.8, 2.6, 3.0	
5	HM-AP-9		1,000	1.8	B2
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
6	HM-AP-20		1,000	1.8, 2.6, 3.0, 3.4	B23
			1,500	1.8, 2.6, 3.0, 3.4	
7	HM-AP-20	HM-AP-20 (unlined)	1,500	1.8, 2.6, 3.0, 3.4	B23
8	HM-AP-20	HM-AP-20 (lined)	1,500	1.8, 2.6, 3.0, 3.4	B23
9	HM-AP-23		540	1.8	B12
			1,000	1.4, 1.6, 1.8, 2.2, 2.6, 3.0, 3.4	
			1,500	1.4, 1.6	
10	HM-AP-23	HM-AP-23	540	1.8	
			1,000	1.4, 1.6, 1.8, 2.2, 2.6, 3.0, 3.4	
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
11	HM-AP-32		1,000	1.8	B17
			1,500	1.8, 2.2, 2.6, 3.0, 3.2	

Test Configuration Index (continued)

Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio	Noise report reference
12	HM-AP-33		1,000 1,500	1.8, 3.0 1.8, 2.2, 2.6, 3.0	
13	HM-AP-36		540 1,000 1,500	1.8 1.8 1.8, 2.2, 2.6, 3.0, 3.2	B24, B25
14	HM-AP-36 (Mod A)		1,000 1,500	1.8 1.8, 2.6, 3.0	B26
15	HM-AP-36 (Mod D)		1,000 1,200 1,500	1.8 2.2 3.0	B26
16	HM-AP-36 (Mod E)		1,000 1,200 1,500	1.8 2.2 3.0	B26
17	HM-AP-36 (Mod F)		1,000 1,200 1,500	1.8 2.2 3.0	B26
18	HM-AP-37		540 1,000 1,500	1.8 1.8 1.8, 2.2, 2.6, 3.0	B3, B18
19	HM-AP-41		1,000 1,500	1.8 1.8, 2.2, 2.6, 3.0	B9, B19
20	HM-AP-41	E1	1,000 1,500	1.8 1.8, 2.2, 2.6, 3.0	B19
21	HM-AP-41	E2	1,000 1,500	1.8 1.8, 2.2, 2.6, 3.0	B19
22	HM-AP-41	E3	1,000 1,500	1.8 1.8, 2.2, 2.6, 3.0	B19
23	HM-AP-41	E4	1,000 1,500	1.8 1.8, 2.2, 2.6, 3.0	B19

Test Configuration Index (continued)

Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio	Noise report reference
24	HM-AP-41	E5	1,000	1.8	B19
			1,500	1.8, 2.2, 2.6, 3.0	
25	HM-AP-41	E6	1,000	1.8	B19
			1,500	1.8, 2.2, 2.6, 3.0	
26	HM-AP-43		540	1.8	B3, B27
			1,000	1.8	
			1,500	1.8, 2.2, 2.6, 3.0	
27	HM-AP-43	HM-AP-43	540	1.8	B27
			1,000	1.8	
			1,500	1.8, 2.2, 2.6, 3.0	None
28	HM-AP-46		1,000	1.8	
			1,500	1.8, 2.6, 3.0	
29	HM-AP-47		1,000	1.4, 1.8, 2.2	
			1,500	1.8, 2.2, 2.6, 3.0	
30	HM-AP-48		1,000	1.8	
			1,500	1.8, 2.6, 3.0	
31	HM-AP-49		1,000	1.8	
			1,500	1.8, 2.6, 3.0	
32	HM-AP-50		1,000	1.8	
			1,500	1.8, 2.6, 3.0	
33	HM-AP-51		1,000	1.8	
			1,500	1.8, 2.6, 3.0	
34	HM-AP-52		1,000	1.8	
			1,500	1.8, 2.6. 3.0	
35	HM-AP-53		1,000	1.4, 1.8, 2.2	
			1,500	1.8, 2.6, 3.0	
36	HM-AP-56		540	1.8	
			1,000	1.8	
			1,500	1.8, 2.6, 3.0, 3.4	

Test Configuration Index (continued)

Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio	Noise report reference
37	HM-AP-56	HM-AP-56	1,000	1.8	
			1,500	1.8, 2.6, 3.0, 3.4	
38	HM-AP-57		1,000	1.8, 2.2, 2.6, 3.0, 3.2, 3.4	B28
			1,500	1.8, 2.2, 2.6, 3.0, 3.2, 3.4	None
39	HM-AP-79		1,000	1.8	
			1,500	1.8, 2.2, 2.6, 3.0	
40	HM-AP-80		1,000	1.8	
			1,500	1.8, 2.2, 2.6, 3.0	
41	HM-AP-81-1		1,000	1.8, 2.2	
			1,500	1.8, 2.2, 2.6, 3.0, 3.2	
42	HM-AP-81-2		1,000	1.8, 2.2	
			1,500	1.8, 2.2, 2.6, 3.0, 3.2	
43	HM-AP-82-1		1,000	1.8, 2.2	
			1,500	1.8, 2.2, 2.6, 3.0, 3.2	
44	HM-AP-82-2		1,000	1.8, 2.2	
			1,500	1.8, 2.2, 2.6, 3.0, 3.2	
45	MPP 152		1,000	1.8, 2.0, 2.2, 2.5, 3.0, 3.4	B22
46	MPP 452		1,000	1.8, 2.0, 2.2, 2.48, 3.0, 3.4	B22
47	253 tubes		1,000	1.8, 2.0, 2.2, 2.48, 3.0, 3.4	B29

B.3 MODEL-SCALE (1/8TH) NOZZLE NOISE AND PERFORMANCE TESTS IN 1968-69

Facility: Hot Nozzle Test Facility, North End Boeing Field, Seattle

Acoustic Data Reference: No formal documentation

Performance Data Reference: (1) Boeing Document D6A12118-1 (Informal), "Multi-Spoke Suppressor Nozzle Characteristics—Volume I—Parametric Thrust Performance"

(2) Boeing Document D6A11822-1 and -2, "Multi-Tube Suppressor Noise Performance—Vols 1 and 2, July 1970

B.3.1 Test Hardware

B.3.1.1 Nozzles

Designation	Description
6.0-in. diameter (standard)	Round convergent nozzle, approximately 1:8 scale of GE 4 engine nozzle; $D_T = 6.0$ in., $A_T = 28.3$ in.^{2}
4.1-in. diameter (standard)	Round convergent nozzle; $D_T = 4.1$ in., $A_T = 13.2$ in.^{2}
HM-AP-35	270 RC tubes, hexagonal annulus configuration, exit cant angle = 15° (inward); AR = 7.0, $A_T = 28.3$ in.^{2}, 2.745-in. tube length
HM-AP-45	36 spokes with flow penetration varying from 60% to 90%; AR = 2.06, $A_T = 28.3$ in.^{2}
HM-AP-55C	37 equally spaced RC tubes, hexagonal array;, AR = 3.33, $A_T = 13.2$ in.^{2}, 5.3-in. tube length. Material: Cr-Ti-Si coated columbium (water-cooled base plate)
HM-AP-58A	42-tube array (six clusters of seven tubes each), with 12 spoke ends on each tube; AR = 9.7, $A_T = 15$ in.^{2}, 7-in. tube length
HM-AP-59A	42-tube annular array with 12 spoke ends on each tube; AR = 8.3, $A_T = 15$ in.^{2}, 7-in. tube length
HM-AP-59B	42-tube annular array with 12 spoke ends on each tube, 21 tubes in the outer row; AR = 8.3, $A_T = 15$ in.^{2}, 7-in. tube length
HM-AP-60	24 spokes with 90% flow penetration; AR = 2.0, $A_T = 13.2$ in.^{2}
HM-AP-61A	42 tubes with 12 spoke ends each in six clusters of tubes surrounding a 24-spoke nozzle (HM-AP-60); AR = 5.2. $A_T = 28.2$ in.^{2}
HM-AP-64A	42 tubes with 12 spoke ends each in an annular configuration surrounding a 24-spoke nozzle (HM-AP-60); AR = 4.4, $A_T = 28.2$ in.^{2}

Designation	Description
HM-AP-65A	42 tubes with 12 spoke ends each in an annular configuration surrounding a 4.1-in.-diameter RC nozzle; AR = 4.4, A_T = 28.2 in.^{2}
HM-AP-78	Combination array of 16 spokes and 16 clusters of tubes (208 tubes total); AR = 3.1, A_T = 28 in.^{2}
HM-AP-85-1	126 equally spaced RC tubes, hexagonal array; AR = 3.33, A_T = 28.1 in.^{2}, 7-in. tube length
HM-AP-85-2	126 equally spaced RC tubes, hexagonal array; AR = 5.2, A_T = 28.1 in.^{2}, 7-in. tube length
HM-AP-85-4	126 equally spaced nonconvergent tubes, hexagonal array; AR = 2.8, A_T = 28.1 in.^{2}, 7-in. tube length
HM-AP-86-1	330 equally spaced RC tubes, hexagonal array; AR = 4.0, A_T = 28.3 in.^{2}, 7-in. tube length
HM-AP-86-2	330 equally spaced RC tubes, hexagonal array; AR = 5.2, A_T = 28.3 in.^{2}, 7-in. tube length
NSC 82	96 elliptical tubes, round array configuration; AR = 2.9, A_T = 26.9 in.^{2}, includes cylindrical ejector
C-D (M_J 1.92)	Convergent-divergent configuration with 6-in.-diameter throat, 7.67-in.-diameter exit; A_9/A_8 = 1.63, A_T = 28.3 in.^{2}

B.3.1.2 Ejectors

Designation	Description
1D-CYL-UL	Cylindrical ejector, 8.6-in. inside diameter, 14 in. long
1D-CYL-L	Cylindrical ejector; 8.6-in. inside diameter, lined with 1-in. fiberglass, 14 in. long
1.2D-CYL-UL	Cylindrical ejector; 10.35-in. inside diameter, 14 in. long
1.2D-CYL-L	Cylindrical ejector; 10.35-in. inside diameter, lined with 1-in. fiberglass, 14 in. long
11 in. x 12 in. D	Cylindrical ejector; 12-in. inside diameter, 11 in. long
16 in. x 12 in. D	Cylindrical ejector; 12-in. inside diameter, 16 in. long
11 in. x 13 in. D	Cylindrical ejector; 13-in. inside diameter, 11 in. long

B.3.2 Test Configuration Index

Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio	Noise report reference
1	6.0-in. diameter (standard)		500	1.6, 1.8, 2.2, 2.6, 3.0, 3.4	
			820	1.5	
			1,000	1.8, 2.2, 2.6, 3.0, 3.4	
			1,120	2.0	
			1,260	2.5	
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
			2,500	2.6, 3.0, 3.4	
			2,800	3.0, 3.4	
2	4.1-in. diameter (standard)		1,500	1.6, 1.8, 2.2, 2.6, 3.0, 3.4	
			2,100	1.8, 2.2, 2.6, 3.0, 3.4	
			2,600	1.8, 2.2, 2.6, 3.0, 3.4	
3	HM-AP-35		500	1.8, 2.2, 2.6, 3.0, 3.4	B25
			1,000	1.8, 2.2, 2.6, 3.0, 3.4	
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
4	HM-AP-35 at 100% conical plug		1,500	1.8, 2.2, 2.6, 3.0, 3.4	B25
5	HM-AP-35 at 60% conical plug		1,500	1.8, 2.2, 2.6, 3.0, 3.4	B25
6	HM-AP-35 at 40% conical plug		1,500	1.8, 2.2, 2.6, 3.0, 3.4	B25
7	HM-AP-35 (240 tubes)		1,500	1.8, 2.2, 2.6, 3.0, 3.4	B25
8	HM-AP-45		1,000	1.8, 2.2, 2.6, 3.0, 3.4	B30, B31
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
9	HM-AP-45	1D-CYL-UL	1,500	1.8, 2.2, 2.6, 3.0, 3.4	B30, B31
10	HM-AP-45	1D-CYL-L	1,500	1.8, 2.2, 2.6, 3.0, 3.4	B30, B31
11	HM-AP-45	1.2D-CYL-UL	1,500	1.8, 2.2, 2.6, 3.0, 3.4	B30, B31

Test Configuration Index (continued)

Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio	Noise report reference
12	HM-AP-45	1.2D-CYL-L	1,500	1.8, 2.2, 2.6, 3.0, 3.4	B30, B31
13	HM-AP-55C		1,600	1.8, 2.2, 2.6 3.0, 3.4	B32
			2,100	1.8, 2.2, 2.6, 3.0, 3.4	B33
			2,600	1.8, 2.2, 2.6, 3.0, 3.4	
14	HM-AP-58A		1,500	1.6, 2.2, 2.6, 3.0, 3.4	B34
15	HM-AP-59A		1,500	1.6, 2.2, 2.6, 3.0, 3.4	B34
16	HM-AP-59B		1,500	1.6, 2.2, 2.6, 3.0, 3.4	B34
17	HM-AP-60		1,500	1.6, 2.2, 2.6, 3.0, 3.4	B34
18	HM-AP-61A		1,500	1.6, 2.2, 2.6, 3.0, 3.4	B34
19	HM-AP-64A		1,500	1.6, 2.2, 2.6, 3.0, 3.4	B34
20	HM-AP-65A		1,500	1.6, 2.2, 2.6, 3.0, 3.4	B34
21	HM-AP-78		500	1.8, 2.2, 2.6, 3.0, 3.4	B35
			1,000	1.8, 2.2, 2.6, 3.0, 3.4	
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
22	HM-AP-85-1		500	1.8, 2.2, 2.6, 3.0, 3.4	B36, B37
			1,000	1.8, 2.2, 2.6, 3.0, 3.4	B38, B39
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	B40
23	HM-AP-85-1	11 in. x 12 in. D	500	1.8, 2.2, 2.6, 3.0, 3.4	B39, B40
			1,000	1.8, 2.2, 2.6, 3.0, 3.4	
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
24	HM-AP-85-1	16 in. x 12 in. D	500	1.8, 2.2, 2.6, 3.0, 3.4	B40
			1,000	1.8, 2.2, 2.6, 3.0, 3.4	
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
25	HM-AP-85-1	11 in. x 13 in. D	500	1.8, 2.2, 2.6, 3.0, 3.4	B40
			1,000	1.8, 2.2, 2.6, 3.0, 3.4	
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	

Test Configuration Index (continued)

Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio	Noise report reference
26	HM-AP-85-2		500	1.8, 2.2, 2.6, 3.0, 3.4	B38
			1,000	1.8, 2.2, 2.6, 3.0, 3.4	
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
27	HM-AP-85-4		500	1.8, 2.2, 2.6, 3.0, 3.4	B41, B42, B38, B43
			1,000	1.8, 2.2, 2.6, 3.0, 3.4	
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
28	HM-AP-85-4 (126-hole plate)		500	1.8, 2.2, 2.6, 3.0, 3.4	B41
			1,000	1.8, 2.2, 2.6, 3.0, 3.4	
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
29	HM-AP-85-4 (elliptical tubes)		500	1.8, 2.2, 2.6, 3.0, 3.4	B43
			1,000	1.8, 2.2, 2.6, 3.0, 3.4	
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
30	HM-AP-85-4	11 in. x 12 in. D	500	1.8, 2.2, 2.6, 3.0, 3.4	B39
			1,000	1.8, 2.2, 2.6, 3.0, 3.4	
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
31	HM-AP-86-1		1,000	1.6	B45
			1,500	2.2, 3.0, 3.4	
32	HM-AP-86		1,000	1.6	B45
			1,500	2.2, 3.0, 3.4	
33	NSC 82		1,500	1.8, 2.2, 2.6, 3.0, 3.4	None
34	NSC 82	NSC 82	1,500	1.8, 2.2, 2.6, 3.0, 3.4	None
			2,400	2.6, 3.0, 3.4	
			2,900	2.6, 3.0	

Test Configuration Index (continued)

Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio	Noise report reference
35	97-hole plate (NSC 82-hole pattern)		500	1.8, 2.2, 2.6, 3.0, 3.4	B46
			820	1.5	
			1,000	1.8, 2.2, 2.6, 3.0, 3.4	
			1,120	2.0	
			1,260	2.5	
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	
36	C-D (M_J 1.92)		65	2.2, 2.6, 3.0, 3.4	None
			500	1.6, 1.8, 2.2, 2.6, 3.0, 3.4	
			1,000	1.8, 2.2, 2.6, 3.0, 3.4	
			1,500	1.8, 2.2, 2.6, 3.0, 3.4	

B.4 FULL-SCALE NOZZLE NOISE AND PERFORMANCE TESTS IN 1968

Facility: Boardman, Oregon Test Site (Pad B-2)
YJ-93 engine

Acoustic Data Reference: Boeing Document D6A11501-1, "Thirty-Six Spoke Jet Noise Suppressor Acoustic and Performance Test Analysis," G. C. Teeter and J. R. Alberti, March 1969

Performance Data Reference: Ibid

B.4.1 Test Hardware

B.4.1.1 Nozzles

Designation	Description
RC	Round convergent nozzle; 603-in.^{2} area at exit plane
HL-AP-9	36-spoke nozzle; AR = 2.2, A_T = 578 in.^{2} (The HM-AP-45 model scale (1:4.7) nozzle was similar to the HL-AP-9 nozzle.)

B.4.1.2 Ejectors

Designation	Description
HL-AP-9	Cylindrical ejector with bellmouth inlet; 49-in. inside diameter, 61 in. long. The inside wall was optionally lined with fiberglass and perforated plates or solid plates.

B.4.2 Test Configuration Index

Configuration	Nozzle	Ejector	Total temperature (°F)	Pressure ratio
1	RC		860	1.4
			1,060	1.8
			1,360	2.3
			1,510	2.6
2	HL-AP-9		760	1.3
			960	1.7
			1,270	2.2
			1,480	2.6
3	HL-AP-9	HL-AP-9	810	1.4
			1,020	1.7
			1,350	2.3
			1,620	2.8
4	HL-AP-9	HL-AP-9 (fiberglass lined)	830	1.4
			1,080	1.8
			1,420	2.4
			1,610	2.8

B.5 REFERENCES

B1 Coordination Sheet SST-ANPD-13, "Cold-Flow Noise Suppression of Various Annulus Type Nozzles," C. P. Wright, 1967.

B2 Coordination Sheet SST-ANPD-18, "Noise Suppression Characteristics of the 6 Lobe Multislot and 24 Spoke Nozzles," R. B. Tate, August 17, 1967.

B3 Coordination Sheet SST-ANPD-52, "Preliminary Acoustics Report on Model Scale Tests of 37 Plain Ended Tube Nozzles," J. R. Alberti, March 18, 1968.

B4 Coordination Sheet SST-ANPD-58, "Noise Characteristics of the Pure Annulus Nozzle (Area Ratio = 4)," C. W. Miller, March 25, 1968.

B5 Coordination Sheet SST-ANPD-64, "Comparison of Pure Annulus and 60-Lobe Annulus Noise Characteristics," C. W. Miller, May 7, 1968.

B6 Coordination Sheet SST-ANPD-129, "Thrust Performance and Noise Suppression Characteristics of the Pure Annular Nozzle Series-HM-AP-12," R. A. Lipka and C. W. Miller, November 1, 1968.

B7 Coordination Sheet SST-ANPD-22, "Effect of Power Setting on the Jet Noise Suppression Characteristics of a 6 Lobe Greatrex Nozzle (HM-AP-15)," R. B. Tate, September 11, 1967.

B8 Coordination Sheet SST-ANPD-16, "A Preliminary Analysis of 37-Tube Array Jet Nozzles, With and Without Greatrex Nozzle Tube Terminations," C. P. Wright, August 16, 1967.

B9 Coordination Sheet SST-ANPD-45, "A Preliminary Analysis of 37-Tube Array Jet Nozzles With 12 Lobe Greatrex—Jet Terminations at 1500° F and Area Ratios of 3.33, 4.0, 4.65, 5.2 and 8.0," C. P. Wright, January 16, 1968.

B10 Coordination Sheet SST-ANPD-94, "Additional Acoustic Data Analysis of the 37-Tube Jet Nozzles with 12-Lobe Greatrex-Type Terminations," C. P. Wright, August 7, 1968.

B11 Coordination Sheet SST-ANPD-17, "Model Tests of the HM-AP-22, 12 Spoke Jet Noise Suppressor Series," J. R. Alberti, August 21, 1967.

B12 Coordination Sheet SST-ANPD-40, "Preliminary Test Results of the Internally Ventilated Jet Noise Suppressor (HM-AP-23)," J. R. Alberti, December 27, 1967.

B13 Coordination Sheet SST-ANPD-31, "High Noise Suppression Program—Five Slot Nozzle Tests HM-AP-24," C. W. Miller, November 10, 1967.

B14 Coordination Sheet SST-ANPD-37, "High Noise Suppression Program—Five Slot Nozzle Tests HM-AP-25," C. W. Miller, December 5, 1967.

B15 Coordination Sheet SST-ANPD-46, "Noise Characteristics of a Five Slot (Area Ratio = 3.0) HM-AP-24 Nozzle," C. W. Miller, January 19, 1968.

B16 Coordination Sheet SST-ANPD-51, "Preliminary Analysis of the 24 Spoke (Area Ratio = 6.0) Nozzle Noise Suppression Characteristics," R. B. Tate, February 21, 1968.

B17 Coordination Sheet SST-ANPD-36, "Preliminary Analysis of the 24 Spoke (Area Ratio = 4.0) Nozzle Noise Suppression Characteristics," R. B. Tate, December 21, 1967.

B18 Coordination Sheet SST-ANPD-77, "Model Scale Retest of 37-Plain Ended Tube Nozzle with an Area Ratio of 4.65," D. H. Underwood, July 11, 1968.

B19 Coordination Sheet SST-ANPD-85, "Suppression Characteristics of a 37-Tube Greatrex Model Jet Nozzle With Various Types of Ejector Shrouds," A. Elston, July 25, 1968.

B20 Coordination Sheet SST-ANPD-94, "Additional Acoustic Data Analysis of the 37-Tube Jet Nozzles with 12-Lobe Greatrex-Type Terminations," C. P. Wright, August 7, 1968.

B21 Coordination Sheet SST-ANPD-14, "Preliminary Results of Recent Noise Suppression Measurements on Model Jet Nozzles, Type MAE4A, MAE152, MPP130-20, MAE53-18, MAE203-3 and MPP452," C. P. Wright, August 1967.

B22 Coordination Sheet SST-ANPD-71, "A Comparison of Measurement Methods Used in Evaluating the Noise Suppression Characteristics of the MPP152 and MPP452 Model Jet Nozzles," A. Elston, June 24, 1968.

B23 Coordination Sheet SST-ANPD-70, "Preliminary Acoustic Report on Model Scale Tests of a Coanda Type Nozzle (HM-AP-20)," J. R. Alberti, June 7, 1968.

B24 Coordination Sheet SST-ANPD-64, "Comparison of Pure Annulus and 60-Lobe Annulus Noise Characteristics," C. W. Miller, May 7, 1968.

B25 Coordination Sheet SST-ANPD-82, "Noise Characteristics of the 60-Lobe Annulus With Concentric Rings," C. E. Burton and C. W. Miller, July 29, 1968.

B26 Coordination Sheet SST-ANPD-186, "Noise Suppression Capability of 60 Lobe Annulus (10° Canted Flow) With and Without Conical Centerbody Plugs," R. B. Tate and C. W. Miller, July 29, 1969.

B27 Coordination Sheet SST-ANPD-90, "Model Scale Test of a 3.33 Area Ratio, 37-Plain Ended Tube Nozzle (HM-AP-43) With a Close-Fitting Ejector," D. H. Underwood, August 7, 1968.

B28 Coordination Sheet SST-ANPD-53, "A Preliminary Acoustic Analysis of a 12 Lobe Greatrex Jet Nozzle Acoustic Noise Characteristics (HM-AP-57)," C. P. Wright, March 26, 1968.

B29 Coordination Sheet SST-ANPD-65, "A Preliminary Acoustic Analysis of a 253 Tube (Area Ratio 4) Jet Nozzle's Accustic Characteristics," C. P. Wright, June 6, 1968.

B30 Coordination Sheet SST-ANPD-109, "A Preliminary Acoustic Analysis of a 36-Spoke Area Ratio 2.06 Jet Nozzle's Noise Characteristics (HM-AP-15)," C. P. Wright, September 26, 1968.

B31 Coordination Sheet SST-ANPD-131, "Thrust Performance and Acoustic Characteristics of a Small Scale 36 Spoke Suppressor Nozzle (J-93 Replica)(AR 2.06)," C. P. Wright and F. G. Strout, November 20, 1968.

B32 Coordination Sheet SST-ANPD-132, "A Preliminary Acoustic Analysis of a 37 Tube Area Ratio 3.33 Jet Nozzle's Noise Characteristics (HM-AP-55)," C. P. Wright, November 26, 1968.

B33 Coordination Sheet SST-ANPD-198, "General Electric JENOTS Facility 37 Tube (3000° F) Suppressor Nozzle Test Results," C. P. Wright, September 12, 1969.

B34 Coordination Sheet SST-ANPD-202, "Tube-Spoke Noise Suppression Parameter Study," A. W. Elston and R. B. Tate (no date).

B35 Coordination Sheet SST-ANPD-159, "Preliminary Acoustic Report on Model Scale Tests of an Area Ratio 3.1, 16 Tubed Spoke Suppressor, HM-AP-78," D. H. Underwood, February 28, 1969.

B36 Coordination Sheet SST-ANPD-150, "A Preliminary Acoustic Analysis of a 126 Tube Area Ratio 3.33 Jet Nozzle's Noise Characteristics (HM-AP-85)," E. A. Wolff and R. B. Tate, March 10, 1969.

B37 Coordination Sheet SST-ANPD-185, "Repeatability of the 126 Tube (Area Ratio 3.33) Nozzle Jet Noise Characteristics," R. B. Tate, July 25, 1969.

B38 Coordination Sheet SST-ANPD-187, "The Effect of Area Ratio on the Suppression Characteristics of a 126 Tube Nozzle," A. W. Elston, August 26, 1969.

B39 Coordination Sheet SST-ANPD-195, "Preliminary Acoustic Evaluation of the 126 Tube Primary Nozzle with Variable Tube Parameters and an Unlined Shroud," R. B. Tate, August 25, 1969.

B40 Coordination Sheet SST-ANPD-200, "Preliminary Acoustic Evaluation of the 126 Tube Primary Nozzle (AR = 3.33) With Variable Unlined Shroud Geometry," R. B. Tate, September 9, 1969.

B41 Coordination Sheet SST-ANPD-176, "Preliminary Acoustic Analysis of an Investigation Test With a 126 Hole, Area Ratio 2.8 Man-Hole Cover Suppressor," D. H. Underwood, June 11, 1969.

B42 Coordination Sheet SST-ANPD-185, "Repeatability of the 126 Tube (Area Ratio 3.33) Nozzle Jet Noise Characteristics," R. B. Tate, July 25, 1969.

B43 Coordination Sheet SST-ANPD-188, "Acoustic Evaluation of a 126 Elliptical Tube (AR = 2.8) Nozzle," R. B. Tate, July 30, 1969.

B44 Coordination Sheet SST-ANPD-205, "Tabulated PNL and PNL Suppression Values for the 330 Tube Nozzle Test Series," J. R. Alberti, October 15, 1969.

B45 Coordination Sheet SST-ANPD-192, "Preliminary Acoustic Analysis of a Test With an Area Ratio 2.93, 97 Hole Man-Hole Cover Suppressor Nozzle," D. H. Underwood, August 15, 1969.

APPENDIX C
PNL SUPPRESSION VALUES FOR EIGHTH-SCALE SUPPRESSOR NOZZLES TESTED

Appendix C shows the PNL suppression (PNdB) as a function of thrust loss for the various model-scale suppressor nozzles tested during the SST high noise suppression program. Figures C-1 through C-15 show the noise suppression and thrust loss relationship of the suppressor nozzles at primary gas conditions of PR = 1.8, 2.2, 2.6, 3.0, and 3.4 and T_T = 500° F, 1,000° F, and 1,500° F.

More detailed nozzle descriptions can be found in appendix D. The values plotted in figures C-1 through C-15 should not be interpreted as being absolute. For instance, noise suppression values are usually consistent for a given jet configuration, but thrust loss is variable, depending on nozzle design parameters affecting secondary flow and base drag.

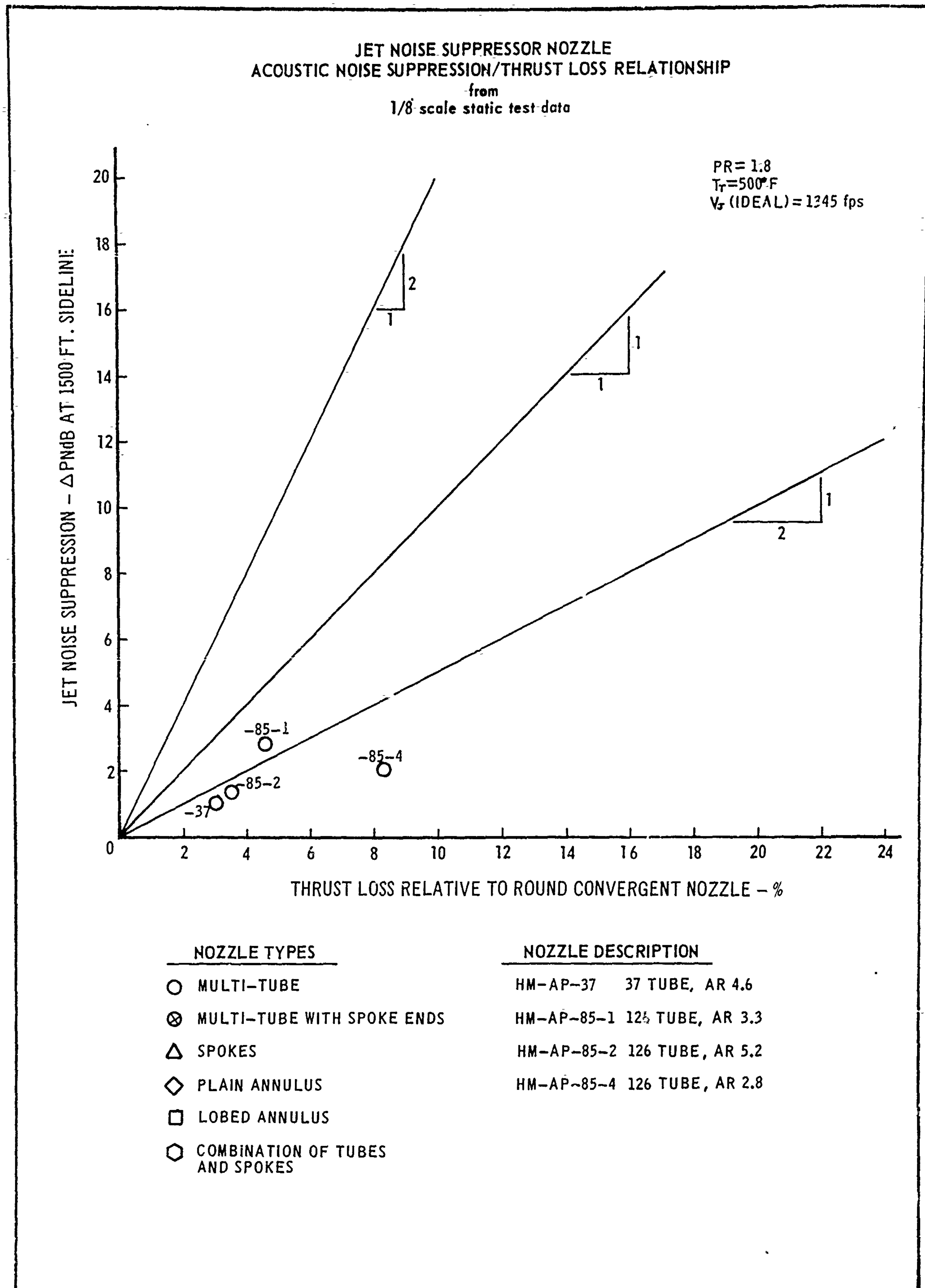


FIGURE C-1.—PR = 1.8, T_T = 500°F, V_J (IDEAL) = 1345 FPS

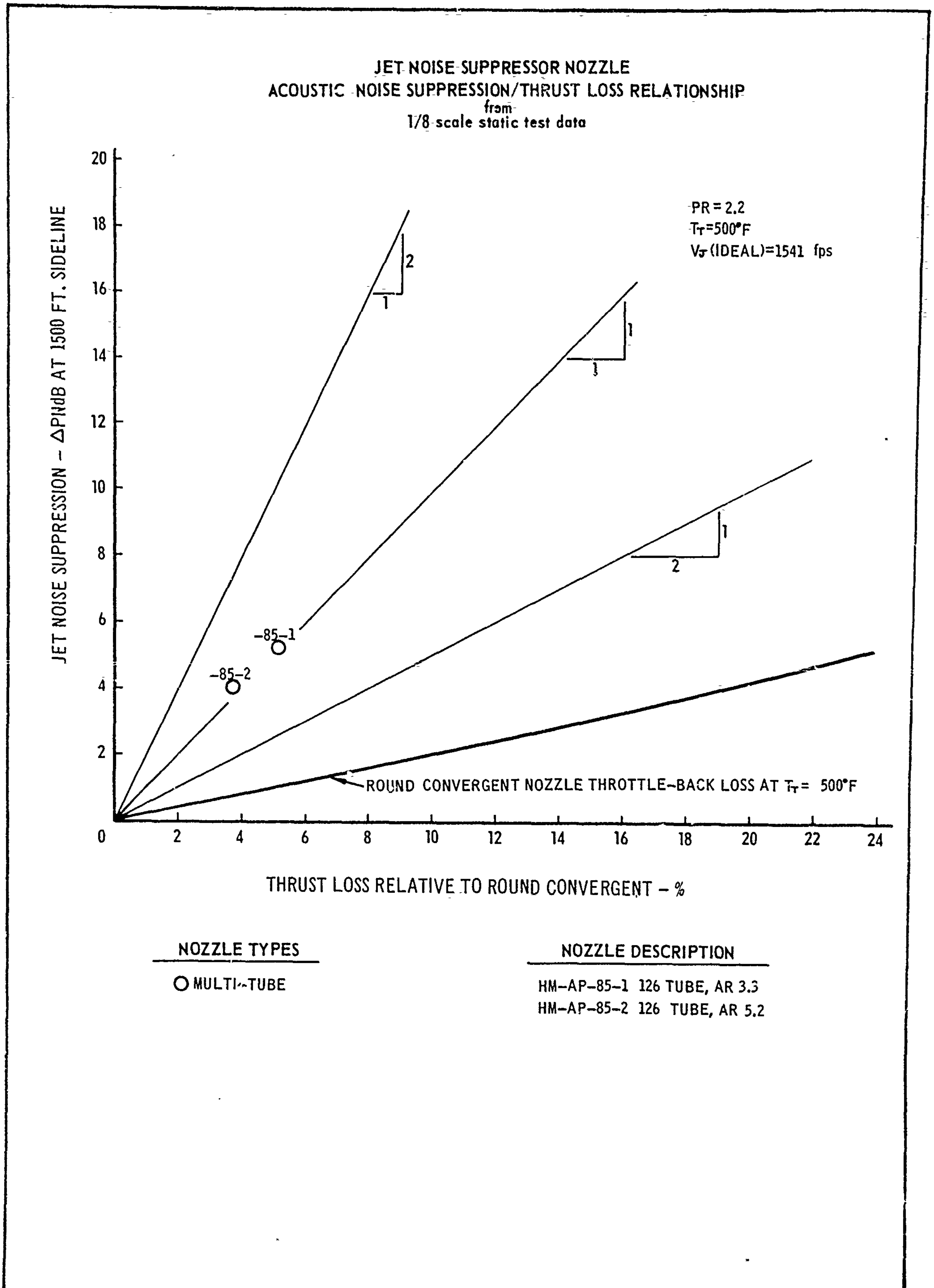


FIGURE C-2.—PR = 2.2, $T_T = 500^\circ F$, V_J (IDEAL) = 1541 FPS

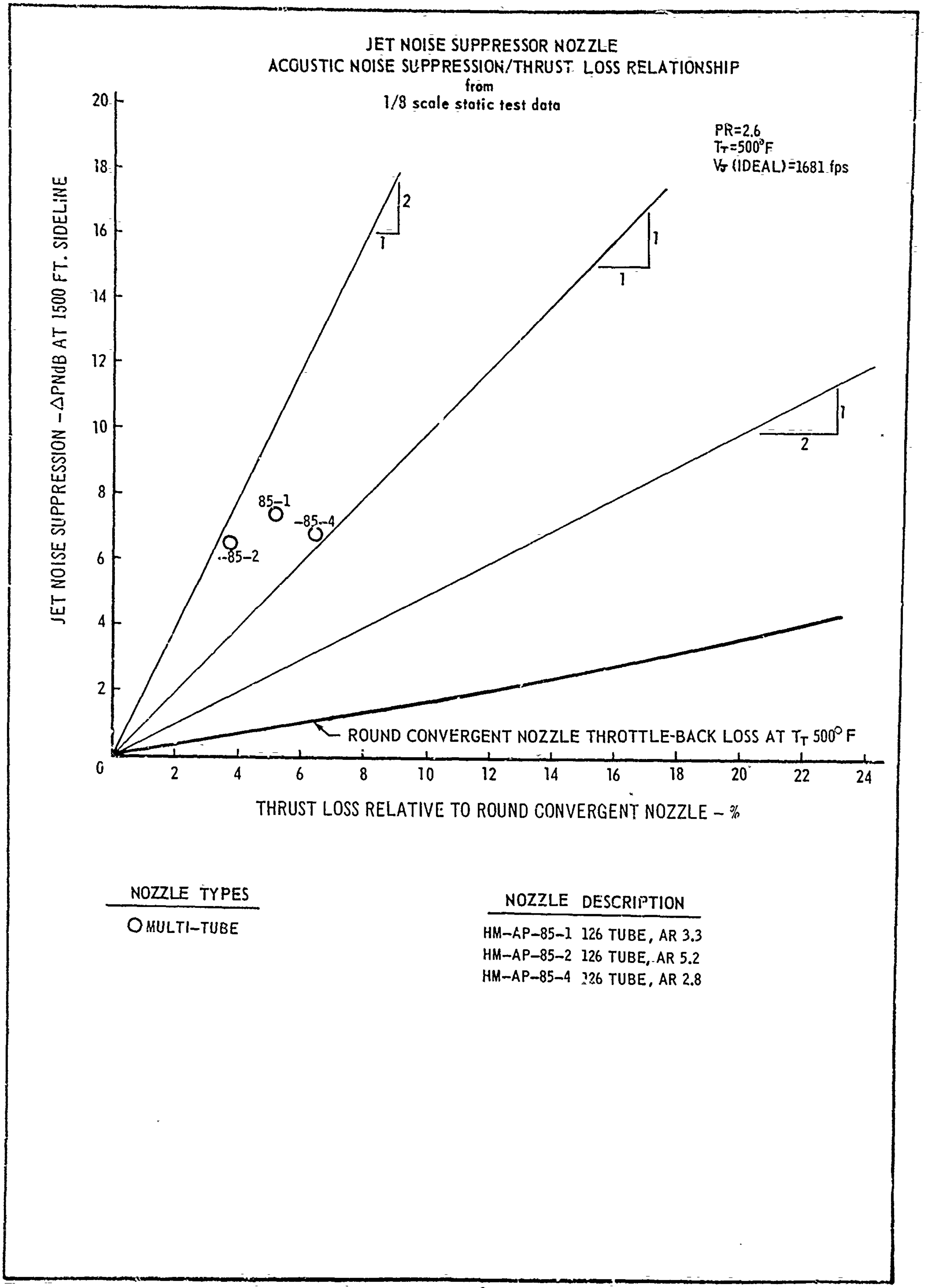


FIGURE C-3.—PR = 2.6, T_T = 500° F, V_J (IDEAL) = 1681 FPS

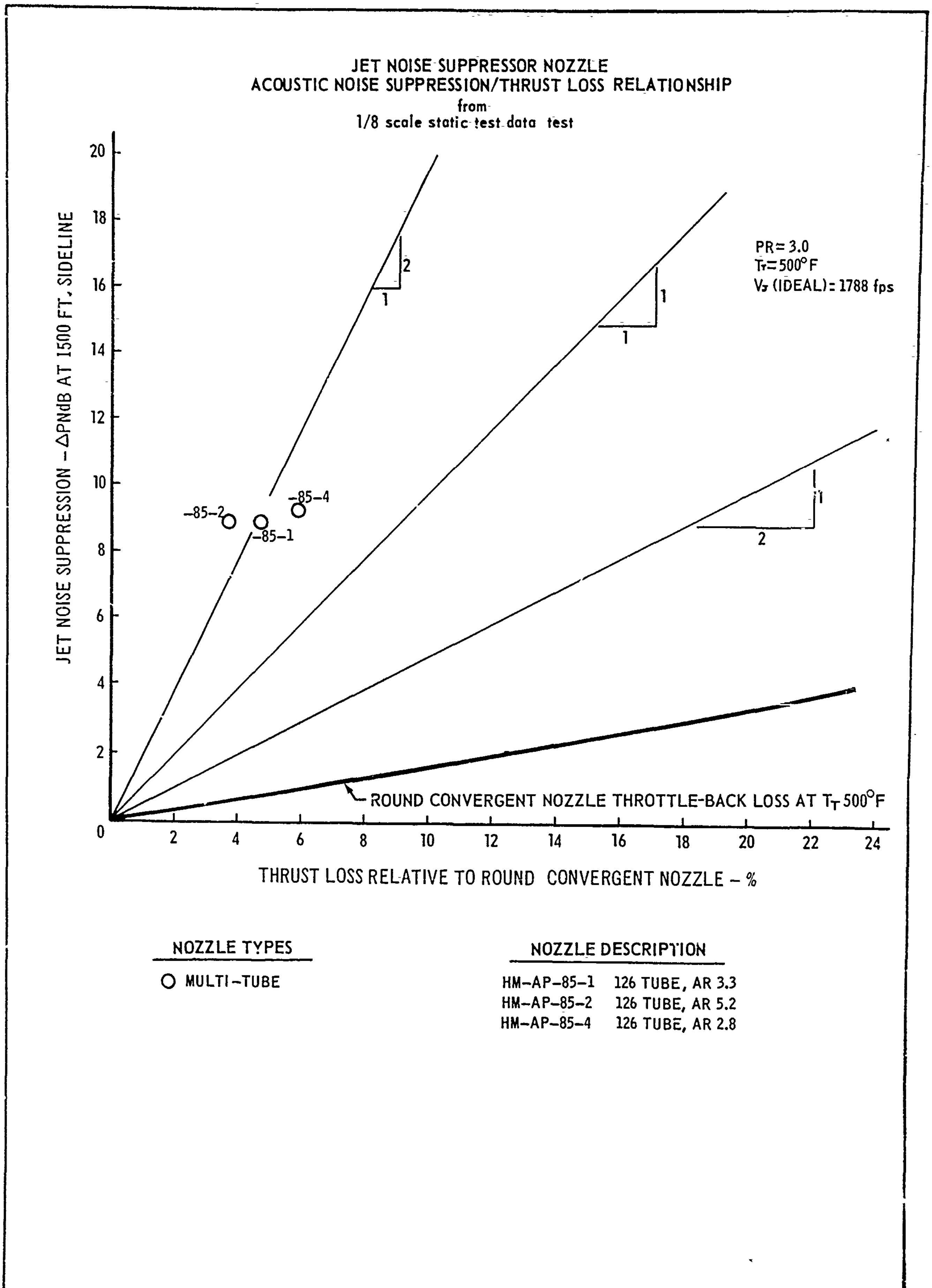


FIGURE C-4.—PR = 3.0, T_T = 500°F, V_J (IDEAL) = 1788 FPS

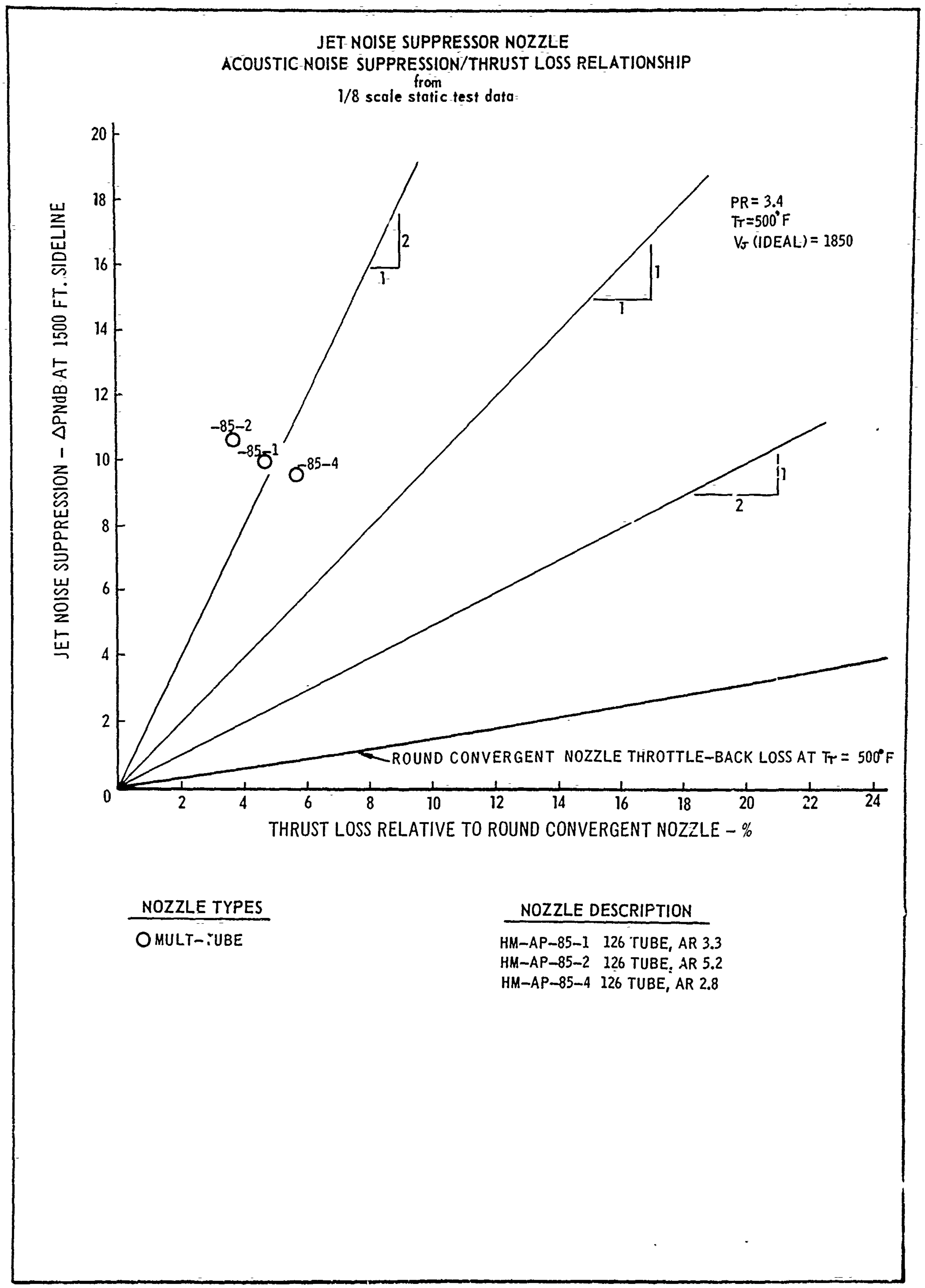
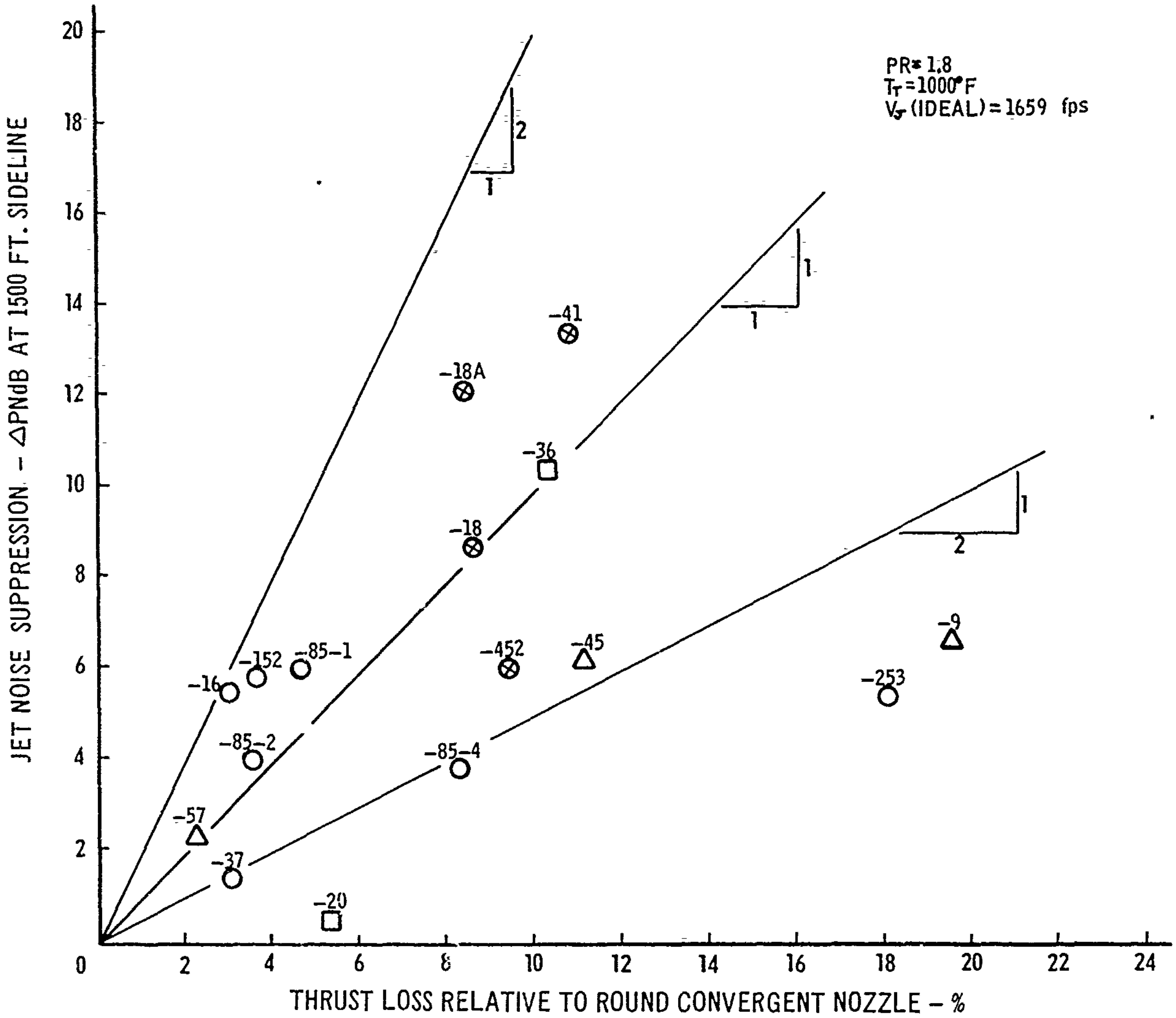


FIGURE C-5.—PR = 3.4, $T_T = 500^\circ F$, V_J (IDEAL) = 1850 FPS

JET NOISE SUPPRESSOR NOZZLE
ACOUSTIC NOISE SUPPRESSION/THRUST LOSS RELATIONSHIP
from
1/8 scale static test data



NOZZLE TYPES

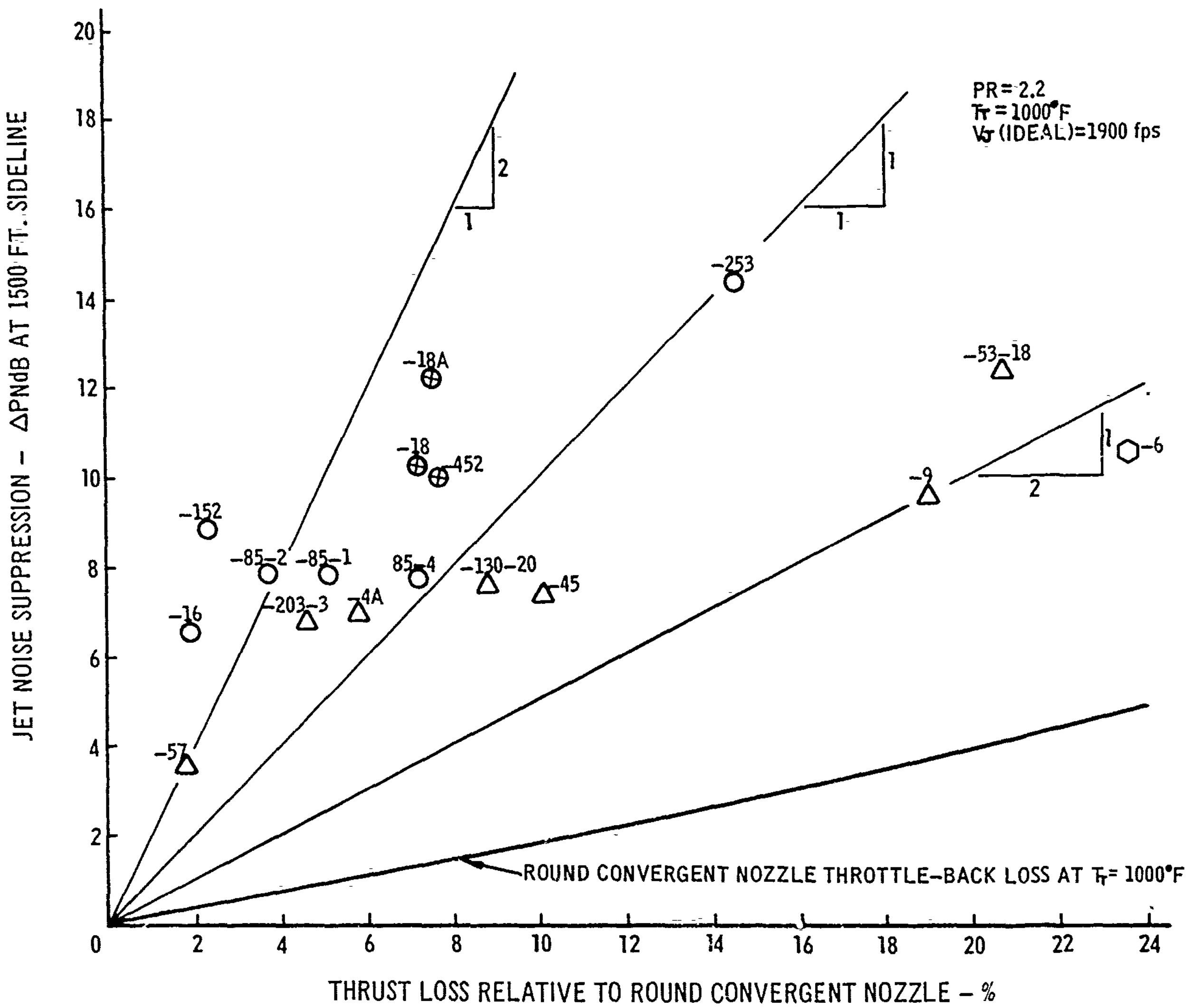
- ○ MULTI- TUBE
- ⊗ MULTI-TUBE WITH SPOKE ENDS
- △ SPOKES
- ◇ PLAIN ANNULUS
- □ LOBED ANNULUS

NOZZLE DESCRIPTION

HM-AP-9 24 SPOKE, AR 1.9
HM-AP-16 37 TUBE, AR 3.3
HM-AP-18 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY, AR 4.65
HM-AP-18A 37 TUBE, 12 SPOKE ENDS, HEX ARRAY, AR 8.0
HM-AP- 20 ANNULAR SLOT/COANDA PLUG, AR 6.5
HM-AP-36 60 LOBE ANNULUS, AR 5.0
HM-AP-37 37 TUBE, AR 4.6
HM-AP-41 37 TUBE/12SPOKE ENDS, HEX ARRAY, AR 4.0
HM-AP-45 36 SPOKE, AR 2.1
HM-AP-57 12 SPOKE, AR 2.1
HM-AP-85-1 126 TUBE, AR 3.3
HM-AP-85-2 126 TUBE, AR 5.2
HM-AP-85-4 126 TUBE, AR 2.8
253 253 TUBE, AR 4.0
MPP-452 21 TUBES, 6 SPOKE ENDS, AR 2.85
MPP-152 21 TUBE, AR 2.4

FIGURE C-6.—PR = 1.8, T_T = 1000°F, V_J (IDEAL) = 1659 FPS

JET NOISE SUPPRESSOR NOZZLE
ACOUSTIC NOISE SUPPRESSION /THRUST LOSS RELATIONSHIP
from
1/8 scale static test data



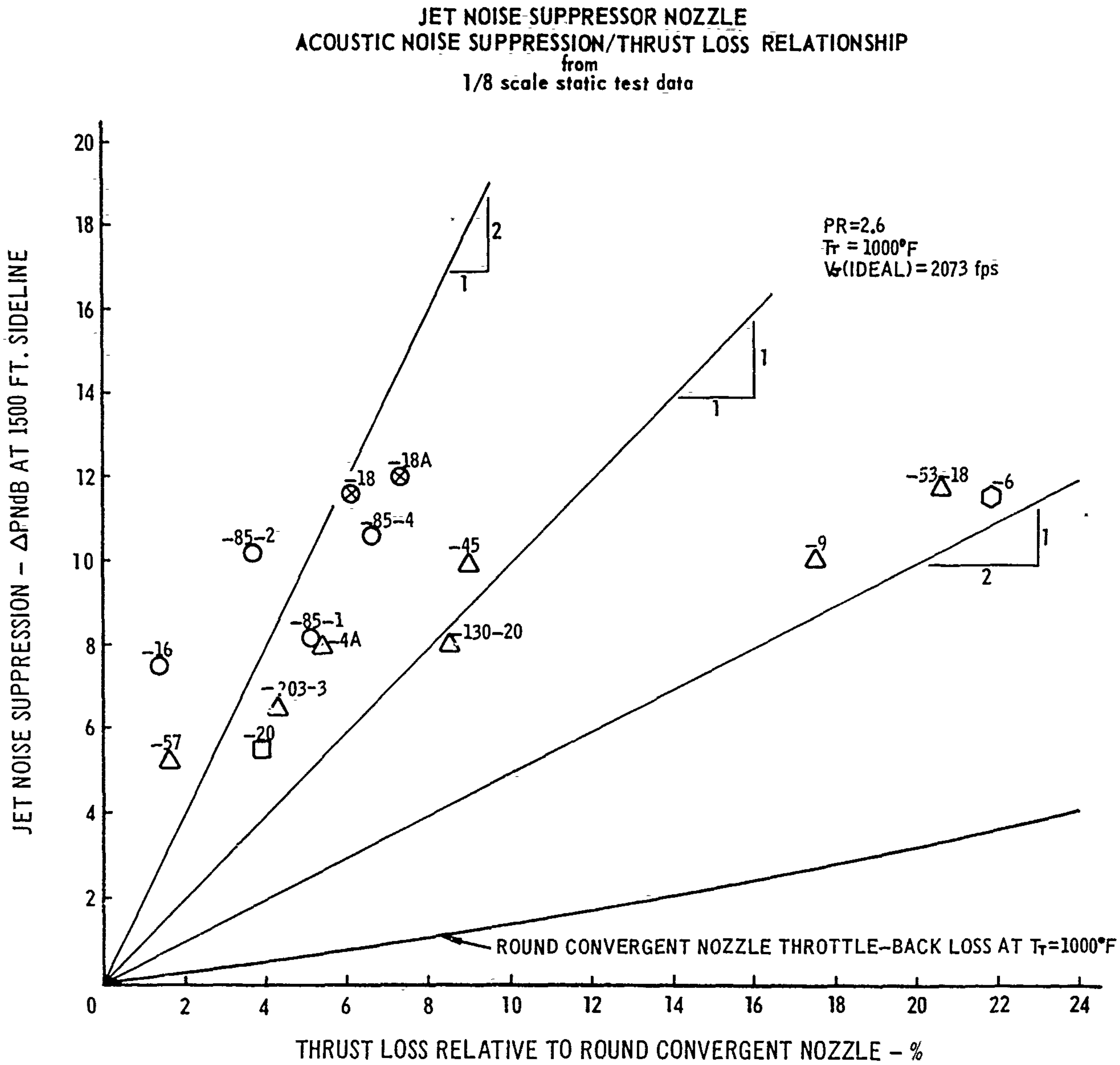
NOZZLE TYPES

○ MULTI-TUBE
⊗ MULTI-TUBE WITH SPOKE ENDS
△ SPOKES
⬡ COMBINATION OF TUBES AND SPOKES

NOZZLE DESCRIPTION

MAE-4A 12 SPOKES/CENTER PLUG, AR 2.9
HM-AP-6 6 SPOKE/MULTI SLOT, AR 8.3
HM-AP-9 24 SPOKE AR 1.9
HM-AP-16 37 TUBE, AR 3.3
HM-AP-18 37 TUBE, 12 SPOKE ENDS, HEX ARRAY, AR 4.65
HM-AP-18A 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY. AR 8.0
HM-AP-45 36 SPOKE, AR 2.1
MAE-53-18 24 SPOKES/ CENTERPLUG AR 2.1
HM-AP-57 12 SPOKE, AR 2.1
HM-AP-85-1 126 TUBE, AR 3.3
HM-AP-85-2 126 TUBE, AR 5.2
HM-AP-85-4 126 TUBE, AR 2.8
MPP-130-20 16 SPOKES, AR 2.25
MAE-203-3 20 SPOKES, AR 2.2
253 253 TUBES, AR 4.0
MPP-452 21 TUBE, 6 SPOKE ENDS, AR 2.86
MPP-152 21 TUBE, AR 2.4

FIGURE C-7.–PR = 2.2, T_T = 1000°F, V_J (IDEAL) = 1900 FPS



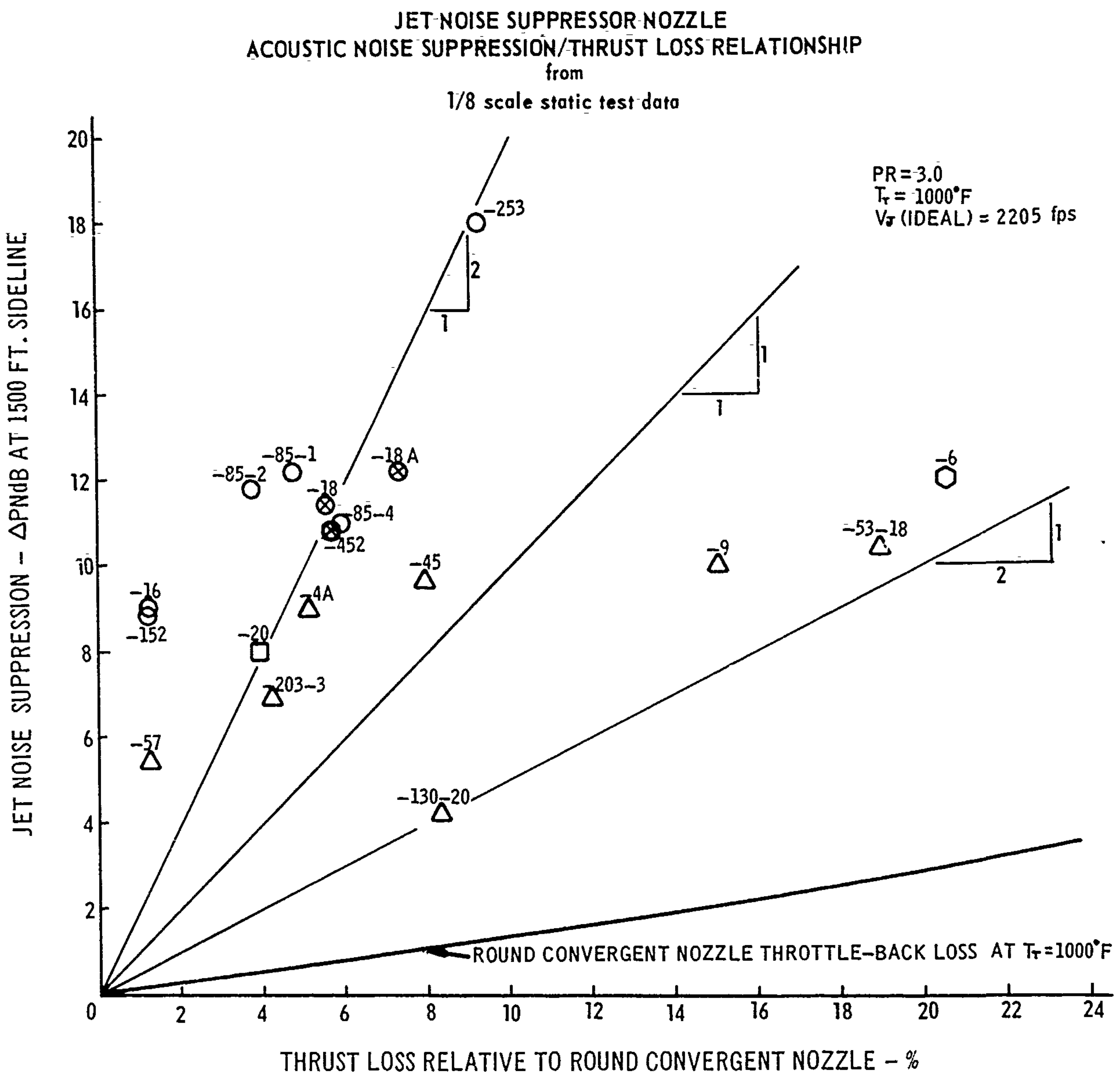
NOZZLE TYPES

- ○ MULTI–TUBE
- ⊗ MULTI–TUBE WITH SPOKE ENDS
- △ SPOKES
- ⬡ COMBINATION OF TUBES AND SPOKES

NOZZLE DESCRIPTION

MAE–4A 12 SPOKES/CENTERPLUG, AR 2.9
HM–AP–6 6 SPOKE/MULTI SLOT, AR 8.3
HM–AP–9 24 SPOKE, AR 1.9
HM–AP–16 37 TUBE, AR 3.3
HM–AP–18 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY, AR 4.65
HM–AP–18A 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY, AR 8.0
HM–AP–20 ANNULAR SLOT/COANDA PLUG. AR 6.5
HM–AP–45 36 SPOKE, AR 2.1
MAE–53–18 24 SPOKES/CENTER PLUG AR 2.1
HM–AP–57 12 SPOKE, AR 2.0
HM–AP–85–1 126 TUBE, AR 3.3
HM–AP–85–2 126 TUBE, AR 5.2
HM–AP–85–4 126 TUBE, AR 2.8
MPP–130–20 16 SPOKES, AR 2.25
MAE–203–3 20 SPOKES, AR 2.2

FIGURE C-8.—PR = 2.6, T_T = 1000°F, V_J (IDEAL) = 2073 FPS



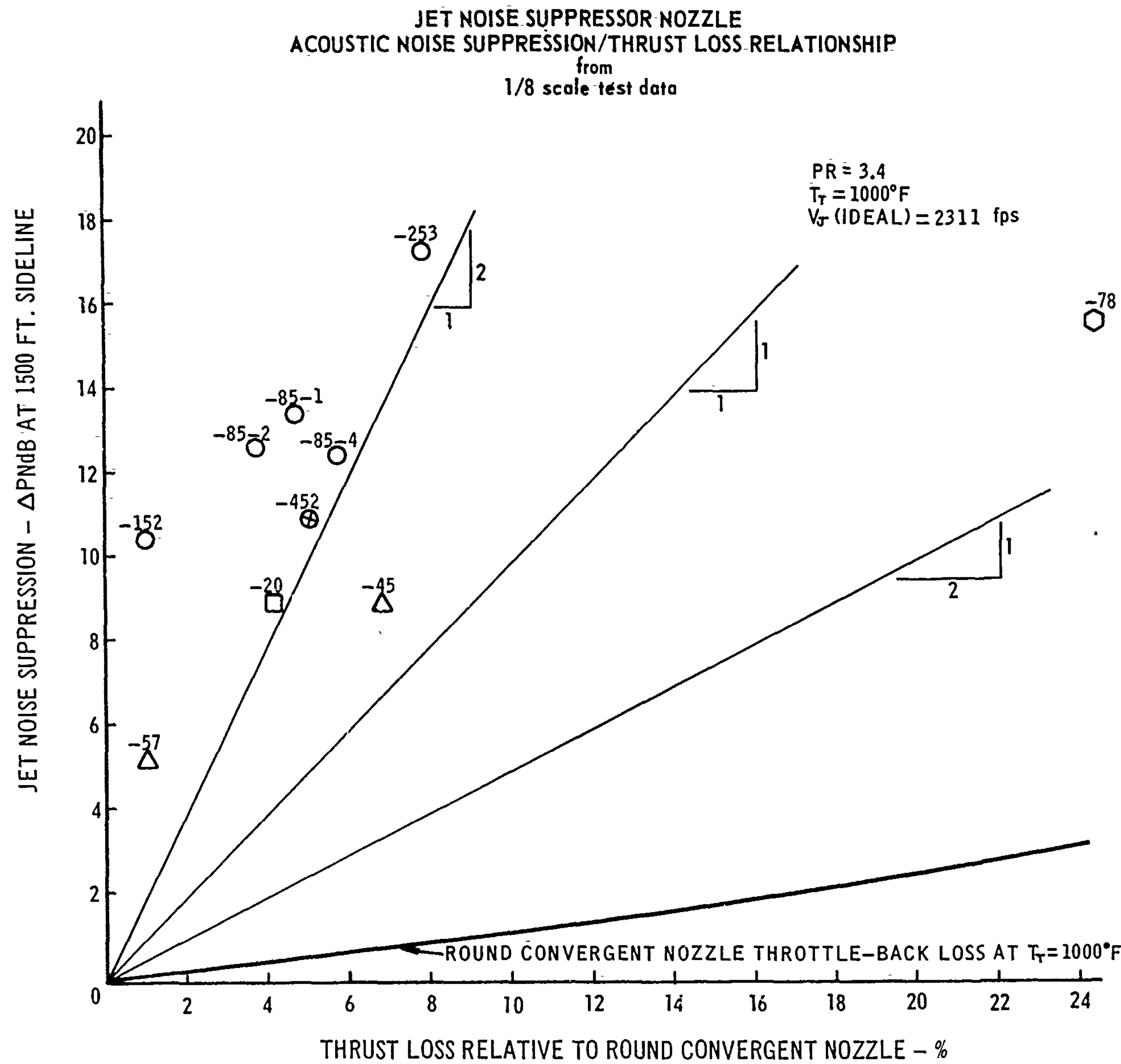
NOZZLE TYPES

- ○ MULTI–TUBE
- ⊗ MULT–TUBE WITH SPOKE ENDS
- △ SPOKES
- ◇ PLAIN ANNULUS
- □ LOBED ANNULUS
- ⬡ COMBINATION OF TUBES AND SPOKES
- ◊ SLOTS

NOZZLE DESCRIPTION

MAE-4A 12 SPOKES/CENTER PLUG, AR 2.9
HM–AP–6 6 SPOKE/ MULTI–SLOT, AR 8.3
HM–AP–9 24 SPOKE, AR 1.9
HM–AP–16 37 TUBE, AR 3.3
HM–AP–18 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY, AR 4.65
HM–AP–18A 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY, AR 8.0
HM–AP–20 ANNULAR SLOT/COANDA PLUG AR 6.5
HM–AP–45 36 SPOKE, AR 2.1
MAE–53–18 24 SPOKES/CENTER PLUG AR 2.1
HM–AP–57 12 SPOKE, AR 2.1
HM–AP–85–1 126 TUBE, AR 3.3
HM–AP–85–2 126 TUBE, AR 5.2
HM –AP–85–4 126 TUBE, AR 2.8
MAE–203–3 29 SPOKES, AR 2.2
MPP– 152 21 TUBE, AR 2.4
MPP–130–20 16 SPOKES, AR 2.25
253 253 TUBES, AR 4.0
MPP–452 21 TUBE, 6 SPOKE ENDS, AR 2.86

FIGURE C-9.—PR = 3.0, T_T = 1000° F, V_J (IDEAL) = 2205 FPS



NOZZLE TYPES

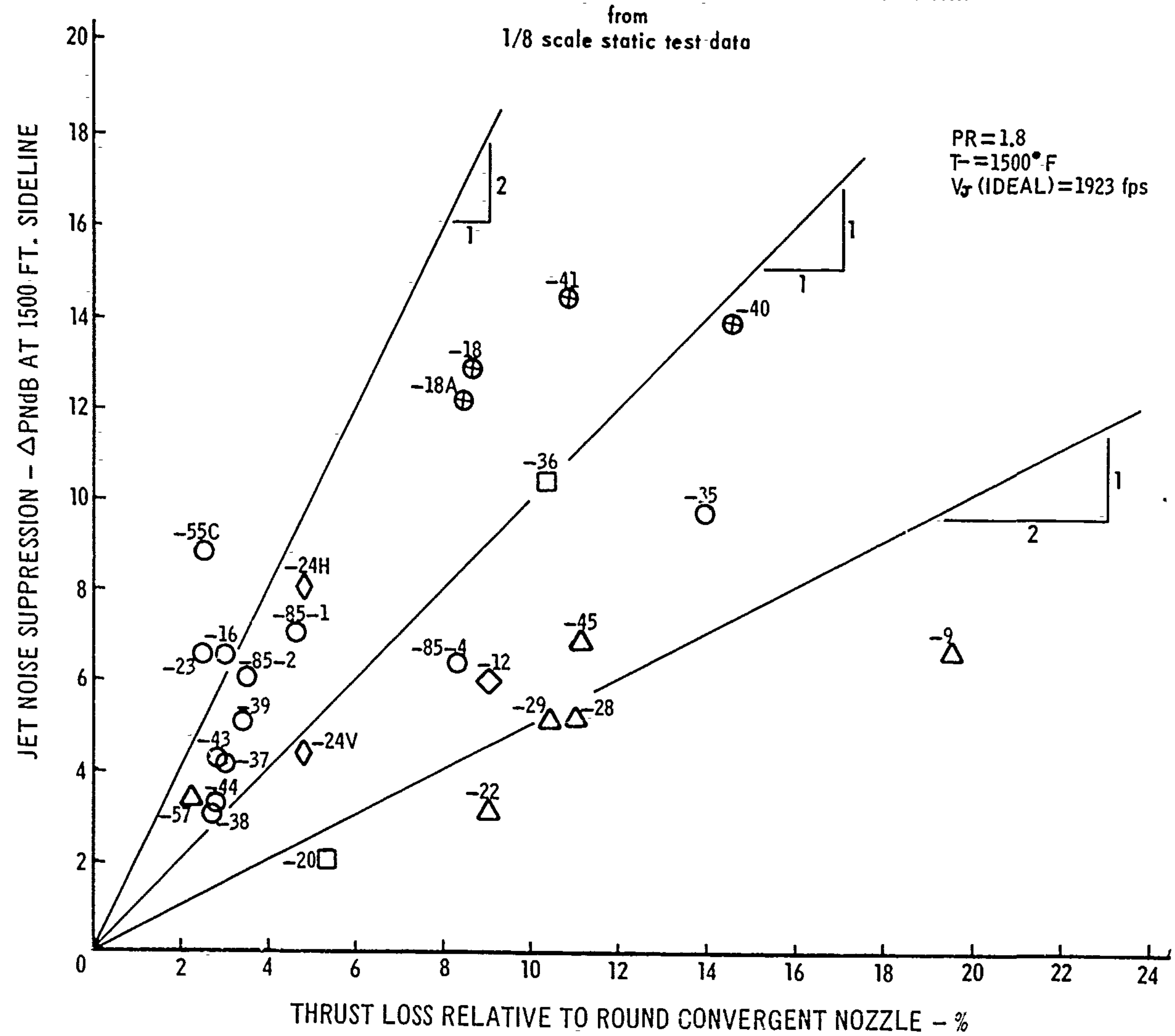
○ MULT-TUBE
⊗ MULTI-TUBE WITH SPOKES ENDS
△ SPOKES
□ LOBED ANNULUS
◇ PLAIN ANNULUS

NOZZLE DESCRIPTION

HM-AP-20 ANNULAR SLOT/COANDA PLUG, AR 6.5
HM-AP-41 37 TUBE/12 SPOKE ENDS, HEX. ARRAY, AR 4.0
HM-AP-45 36 SPOKE, AR 2.1
HM-AP-57 12 SPOKE, AR 2.1
HM-AP-85-1 126 TUBE, AR 3.3
HM-AP-85-2 126 TUBE, AR 5.2
HM-AP-85-4 126 TUBE, AR 2.8
HM-AP-253 253 TUBES, AR 4.0
HM-AP-452 21 TUBE, 6 SPOKE ENDS, AR 2.86
HM-AP-152 21 TUBE, AR 2.4
HM-AP-78 16 SPOKES AND 208 TUBES, AR 3.1

FIGURE C-10.—PR = 3.4, T_T = 1000°F, V_J (IDEAL) = 2311 FPS

JET NOISE SUPPRESSOR NOZZLE
ACOUSTIC NOISE SUPPRESSION/THRUST LOSS RELATIONSHIP
from
1/8 scale static test data



NOZZLE TYPES

- ○ MULTI-TUBE
- ⊗ MULTI-TUBE WITH SPOKE ENDS
- △ SPOKES
- ◇ PLAIN ANNULUS
- □ LOBED ANNULUS
- ⬡ COMBINATION OF TUBES AND SPOKES
- ◊ SLOTS

NOZZLE DESCRIPTION

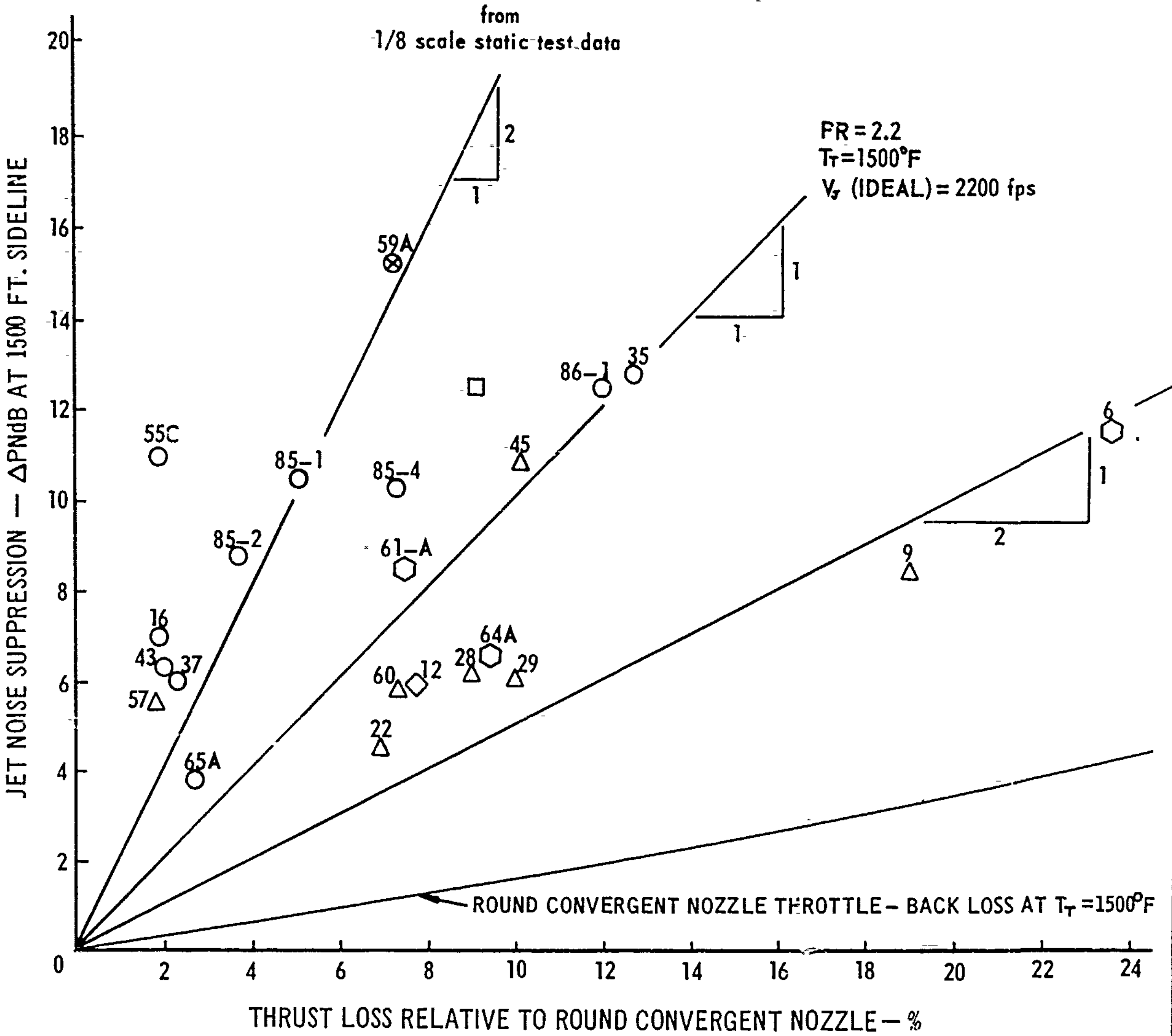
HM-AP-57 12 SPOKE, AR 2.1
HM-AP-85-1 126 TUBE, AR 3.3
HM-AP-85-2 126 TUBE AR 5.2
HM-AP-85-4 126 TUBE, AR 4.0
HM-AP-36 60 LOBE ANNULUS, AR 5.0

NOZZLE DESCRIPTION

HM-AP-9 24 SPOKE, AR 1.9
HM-AP-12 ANNULUS, AR 4.0
HM-AP-16 37 TUBE, AR 3.3
HM-AP-18 37 TUBE, 12 SPOKE ENDS, HEX ARRAY, AR 4.65
HM-AP-18A 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY, AR 8.0
HM-AP-20 ANNULAR SLOT/COANDA PLUG, AR 6.5
HM-AP-22 15 SPOKE, AR 1.4
HM-AP-23 7 TUBES(INTERNALLY VENTILATED) AR 1.8
HM-AP-24H 5 PARALLEL SLOTS, HORIZONTAL AR 3.0
HM-AP-24V 5 PARALLEL SLOTS, VERTICAL AR 3.0
HM-AP-28 24 SPOKE, AR 6.0
HM-AP-29 24 SPOKE, AR 6.0
HM-AP-35 270 TUBES ANNULUS, HEX-ANNUL ARRAY, AR 7.0
HM-AP-37 37 TUBE, AR 4.6
HM-AP-38 37 TUBE, HEX. ARRAY, AR 8.0
HM-AP-39 37 TUBE, HEX. ARRAY, AR 4.0
HM-AP-40 37 TUBE, 12 SPOKE ENDS HEX. ARRAY, AR 3.33
HM-AP-41 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY, AR 4.0
HM-AP-43 37 TUBE, AR 3.3
HM-AP-44 37 TUBE, HEX. ARRAY, AR 5.2
HM-AP-45 36 SPOKE, AR 2.1
HM-AP-55C 37 TUBE, AR 3.3

FIGURE C-11.—PR = 1.8, T_T = 1500°F, V_J (IDEAL) = 1923 FPS

JET NOISE SUPPRESSOR NOZZLE
ACOUSTIC NOISE SUPPRESSION/THRUST LOSS RELATIONSHIP
from
1/8 scale static test data



NOZZLE TYPES

- ○ MULTI TUBE
- ⊗ MULTI-TUBE WITH 12 SPOKE ENDS
- △ SPOKES
- ◇ PLAIN ANNULUS
- □ LOBED ANNULUS
- ⬡ COMBINATION OF TUBES AND SPOKES

NOZZLE DESCRIPTION

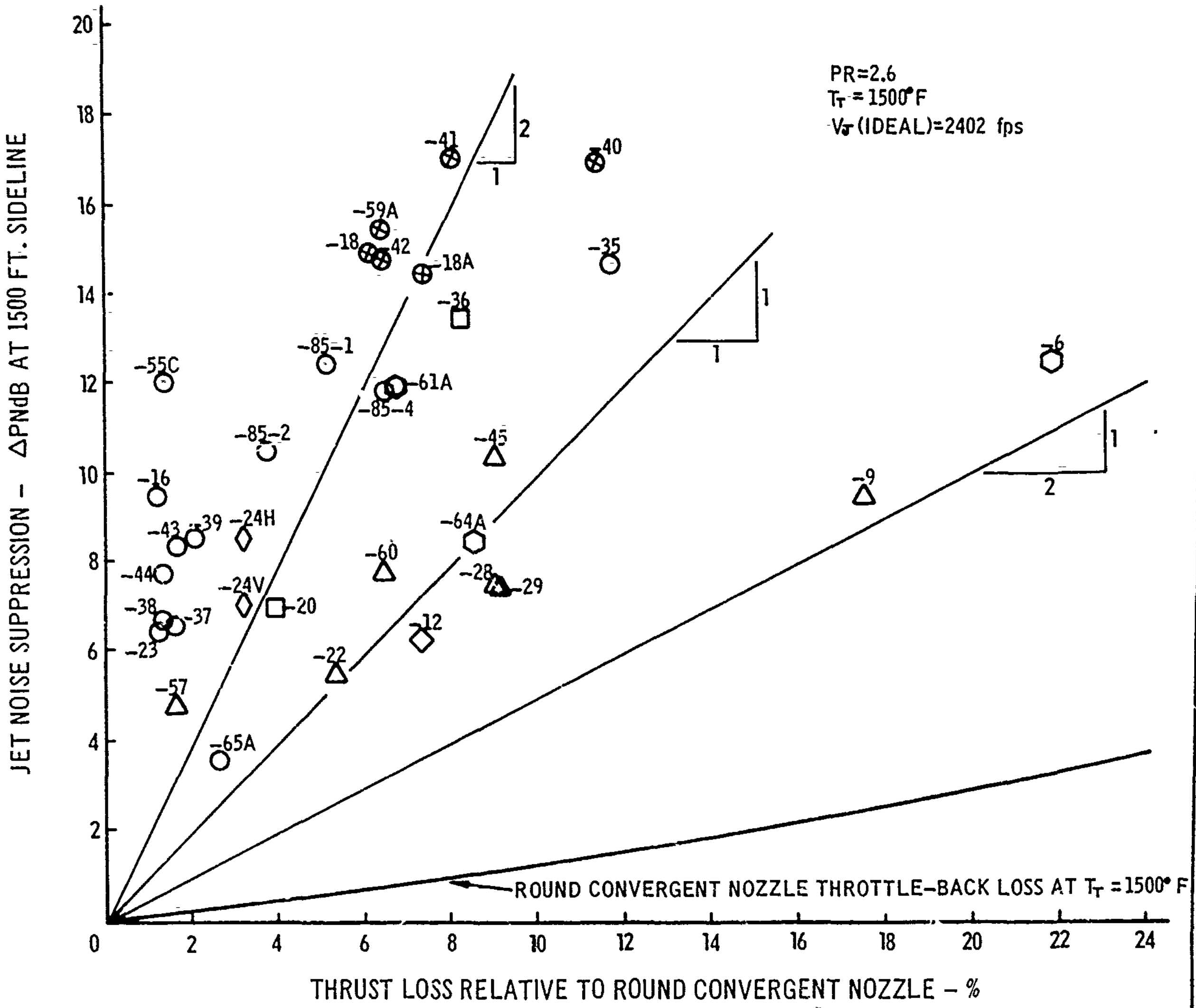
HM-AP-28 24 SPOKE, AR 6.0
HM-AP-12 ANNULUS, AR 4.0
HM-AP-36 60 LOBE ANNULUS, AR 5.0
HM-AP-61A 42 TUBE/24 SPOKE AR 5.2
HM-AP-64A 42 TUBE/ 24 SPOKE AR 4.4
HM-AP-6 6 SPOKE/MULTI SLOT, AR 8.3

NOZZLE DESCRIPTION

HM-AP-55C 37 TUBE, AR 3.3
HM-AP-85-1 126 TUBE, AR 3.3
HM-AP-85-2 126 TUBE, AR 5.2
HM-AP-16 37 TUBE, AR 3.3
HM-AP-43 37 TUBE, AR 3.3
HM-AP-37 37 TUBE, AR 4.6
HM-AP-85-4 126 TUBE, AR 2.8
HM-AP-86-1 330 TUBE, AR 4.0
HM-AP-35 270 TUBE ANNULUS, AR 7.0
HM-AP-65A 42 TUBE/4.1 RC, AR 4.4
HM-AP-59A 42 TUBE, AR 8.3
HM-AP-22 15 SPOKE, AR 1.4
HM-AP-60 24 SPOKE AR 2.0
HM-AP-29 24 SPOKE, AR 6.0
HM-AP-45 36 SPOKE, AR 2.1
HM-AP-57 12 SPOKE, AR 2.1
HM-AP-9 24 SPOKE, AR 1.9

FIGURE C-12.—PR = 2.2, T_T = 1500° F, V_J (IDEAL) = 2200 FPS

JET NOISE SUPPRESSOR NOZZLE
ACOUSTIC NOISE SUPPRESSION/THRUST LOSS RELATIONSHIP
from
1/8 scale static test data



NOZZLE TYPES

- ○ MULT-TUBE
- ⊗ MULTI-TUBE WITH SPOKE ENDS
- △ SPOKES
- ◇ PLAIN ANNULUS
- □ LOBED ANNULUS
- ⬡ COMBINATION OF TUBES AND SPOKES
- ◊ SLOTS

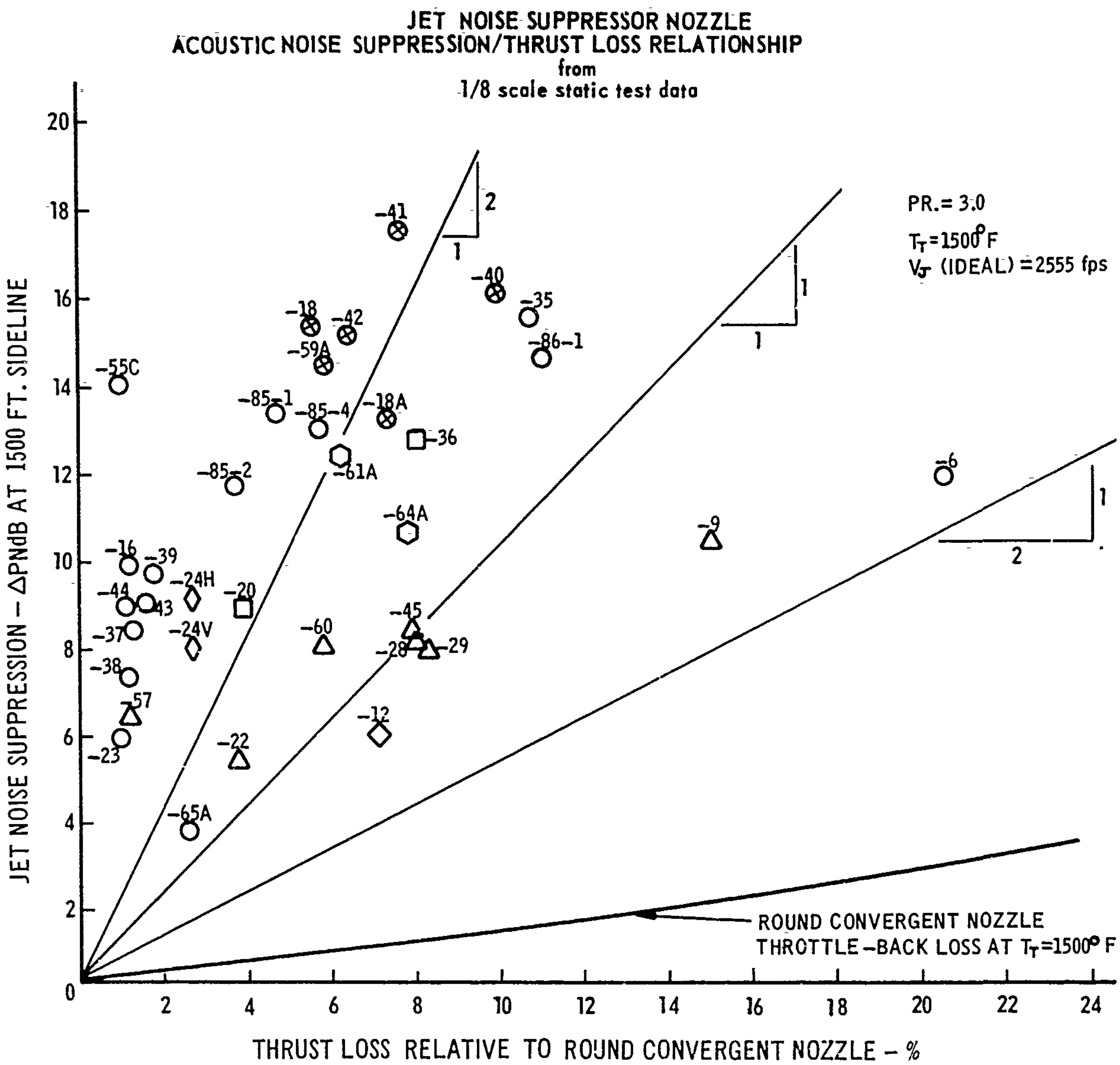
NOZZLE DESCRIPTION

HM-AP-45 36 SPOKE, AR 2.1
HM-AP-85-4 126 TUBE, AR 2.8
HM-AP-55C 37 TUBE, AR 3.3
HM-AP-57 12 SPOKE, AR 2.1
HM-AP-59A 42 TUBE, AR 8.3
HM-AP-60 24 SPOKE, AR 2.0
HM-AP-61A 42 TUBE/ 24 SPOKE, AR 5.2
HM-AP-64A 42 TUBE/ 24 SPOKE AR 4.4
HM-AP-65A 42 TUBE, 4.1 RC, AR 4.4
HM-AP-85-1 126 TUBE, AR 3.3
HM-AP-85-2 126 TUBE, AR 5.2

NOZZLE DESCRIPTION

HM-AP-6 6 SPOKE, / MULTI SLOT, AR 8.3
HM-AP-9 24 SPOKE, AR 1.9
HM-AP-12 ANNULUS, AR 4.0
HM-AP-16 37 TUBE, AR 3.3
HM-AP-18 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY, AR 4.65
HM-AP-18A 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY, AR 8.0
HM-AP-20 ANNULAR SLOT/COANDA PLUG, AR 6.5
HM-AP- 22 15 SPOKE AR 1.4
HM-AP-23 7 TUBES (INTERNALLY VENTILATED) AR 1.8
HM-AP-24H 5 PARALLEL SLOTS, HORIZONTAL AR 3.0
HM-AP-24V 5 PARALLEL SLOTS, VERTICAL, AR 3.0
HM-AP-28 24 SPOKE, AR 6.0
HM-AP-29 24 SPOKE, AR 6.0
HM-AP-35 270 TUBE ANNULUS, HEX-ANNUL ARRAY, AR 7.0
HM-AP-36 60 LOBE ANNULUS, AR 5.0
HM-AP-38 37 TUBE, HEX ARRAY, AR 8.0
HM-AP-39 37 TUBE, HEX ARRAY, AR 4.0
HM-AP-40 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY AR 3.33
HM-AP-41 37 TUBE /12 SPOKE ENDS, HEX. ARRAY, AR 4.0
HM-AP-42 37 TUBE 12 SPOKE ENDS HEX ARRAY AR 5.2
HM-AP-43 37 TUBE, AR 3.3
HM-AP-44 37 TUBE, HEX ARRAY, AR 5.2

FIGURE C-13.–PR = 2.6, T_T = 1500°F, V_J (IDEAL) = 2402 FPS



NOZZLE TYPES

- ○ MULTI–TUBE
- ⊗ MULTI–TUBE WITH SPOKE ENDS
- △ SPOKES
- ◇ PLAIN ANNULUS
- □ LOBED ANNULUS
- ⬡ COMBINATION OF TUBES AND SPOKES
- ◊ SLOTS

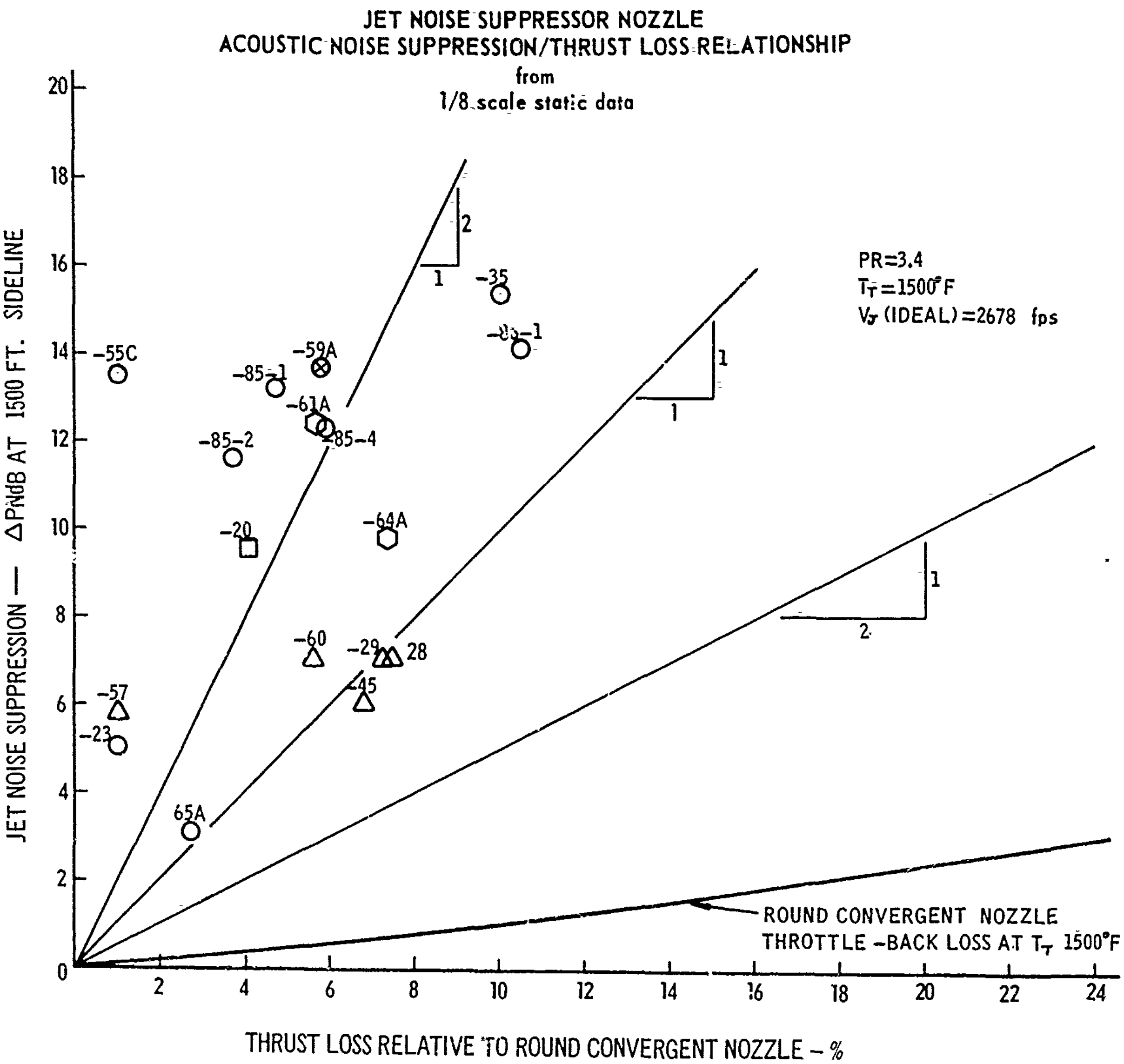
NOZZLE DESCRIPTION

HM–AP–44 37 TUBE, HEX. ARRAY, AR 5.2
HM–AP–55C 37 TUBE, AR 3.3
HM–AP–57 12 SPOKE, AR 2.1
HM–AP–59A 42 TUBE, AR 8.3
HM–AP–60 24 SPOKE, AR 2.0
HM–AP–61A 42 TUBE/24 SPOKE, AR 5.2
HM–AP–64A 42 TUBE/24 SPOKE AR 4.4
HM–AP–65A 42 TUBE/4.1 RC, AR 4.4
HM–AP–85–1 126 TUBE, AR 3.3
HM–AP–85–2 126 TUBE, AR 5.2
HM–AP–85–4 126 TUBE, AR 2,8
HM–AP–86–1 330 TUBES, AR 4.0
HM–AP–45 36 SPOKE, AR 2.1

NOZZLE DESCRIPTION

HM–AP–6 6 SPOKES/MULTI SLOT, AR 8.3
HM–AP–9 24 SPOKES, AR 1.9
HM–AP–12 ANNULUS, AR 4.0
HM–AP–16 37 TUBE, AR 3.3
HM–AP–18 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY, AR 4.65
HM–AP–18A 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY, AR 8.0
HM–AP–20 ANNULAR SLOT/COANDA PLUG, AR 6.5
HM–AP–22 15 SPOKE AR 1.4
HM–AP–23 7 TUBES (INTERNALLY VENTILATED), AR 1.8
HM–AP–24H 5 PARALLEL SLOTS, HORIZONTAL, AR 3.0
HM–AP–24V 5 PARALLEL SLOTS, VERTICAL AR 3.0
HM–AP–28 24 SPOKE, AR 6.0
HM–AP–29 24 SPOKE, AR 6.0
HM–AP–35 270 TUBE ANNULUS, HEX. –ANUL. ARRAY AR. 7.0
HM–AP–36 60 LOBE ANNULUS, AR 5.0
HM–AP–37 37 TUBE, AR 4.6
HM–AP–38 37 TUBE, HEX. ARRAY, AR 8.0
HM–AP–39 37 TUBE HEX. ARRAY, AR 4.0
HM–AP–40 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY, AR 3.33
HM–AP–41 37 TUBE, 12 SPOKE ENDS, HEX ARRAY, AR 4.0
HM–AP–42 37 TUBE, 12 SPOKE ENDS, HEX. ARRAY, AR 5.2
HM–AP–43 37 TUBE, AR 3.3

FIGURE C-14.–PR = 3.0, T_T = 1500° F, V_J (IDEAL) = 2555 FPS



NOZZLE TYPES
○ MULTI-TUBE
⊗ MULTI-TUBE WITH SPOKE ENDS
△ SPOKES
◇ PLAIN ANNULUS
□ LOBED ANNULUS
⬡ COMBINATION OF TUBES AND SPOKES

NOZZLE DESCRIPTION

HM-AP-20 ANNULAR SLOT WITH (CONDA TYPE PLUG) AR 6.5
HM-AP-23 7 TUBES (INTERNALLY VENTILATED), AR 1.8
HM-AP-29 24 SPOKE, AR 6.0
HM-AP-35 270 TUBE, HEXAGONAL ANNULUS ARRAY, AR 7.0
HM-AP-45 36 SPOKE, AR 2.1
HM-AP-55C 37 TUBE, AR 3.3
HM-AP-57 12 SPOKE, AR 2.1
HM-AP-28 24 SPOKE, AR 6.0
HM-AP-60 24 SPOKE, AR 2.0
HM-AP-64A 42 TUBE/24 SPOKE AR 4.4
HM-AP-65A 42 TUBE/4.1" RC, AR 4.4
HM-AP-85-1 126 TUBE, AR 3.3
HM-AP-85-2 126 TUBE, AR 5.2
HM-AP-85-4 126 TUBE, AR 2.8
HM-AP-86-1 330 TUBE, AR 4.0

FIGURE C-15.—PR = 3.4, T_T = 1500°F, V_J (IDEAL) = 2678 FPS

APPENDIX D
SST 12-20 PNdB SUPPRESSION PROGRAM NOZZLES AND THEIR NOISE AND THRUST CHARACTERISTICS

D.1 NOZZLES TESTED (MODEL SCALE)

The list below contains the model-scale nozzles tested and their locations in the compendium. Some nozzles are not included because the acoustic data were in the process of analysis when the SST program was terminated and the results are incomplete.

Nozzle	Description	Page
HM-AP-6	6 lobes, multislot, AR = 8.28	D5
HM-AP-9	24 spokes, AR = 1.9	D15
HM-AP-12	Annulus, AR = 4.0	D25
HM-AP-15	6 spokes, AR = 1.6	D32
HM-AP-16	37-tube hexagonal array, AR = 3.33	D48
HM-AP-18	37-tube (12 spoke ends) hexagonal array, AR = 4.65	D56
HM-AP-18a	37-tube (12 spoke ends) hexagonal array, AR = 8.0	D64
HM-AP-20	Annular slot with coanda-type plug, AR = 6.5	D72
HM-AP-22	12 spokes, AR = 1.4	D80
HM-AP-23	7 tubes, internally ventilated, AR = 1.8	D87
HM-AP-24	5 parallel slots, AR = 3.0	D95
HM-AP-28	24 spokes, AR = 6.0	D105
HM-AP-29	24 spokes, AR = 6.0	D112 1
HM-AP-32	24 spokes, AR = 4.0	D113
HM-AP-33	36 spokes, AR = 4.0	D121 2
HM-AP-35	270-tube annulus, AR = 7.0	D122
HM-AP-36	Annulus array of 60 slots, AR = 5.0	D130
HM-AP-37	37-tube hexagonal array, AR = 4.65	D137
HM-AP-38	37-tube hexagonal array, AR = 8.0	D144
HM-AP-39	37-tube hexagonal array, AR = 4.0	D151
HM-AP-40	37-tube (12 spoke ends) hexagonal array, AR = 3.33	D158
HM-AP-41	37-tube (12 spoke ends) hexagonal array, AR = 4.0	D165
HM-AP-42	37-tube (12 spoke ends) hexagonal array, AR = 5.2	D172
HM-AP-43	37-tube hexagonal array, AR = 3.33	D179
HM-AP-44	37-tube hexagonal array, AR = 5.2	D186
HM-AP-45	36 spokes, AR = 2.06	D193
HM-AP-46	49 RC tubes arranged in 7-tube (AR = 3.0) clusters, AR = 5.2	2
HM-AP-47	49 tubes (12 spoke ends) arranged in 7-tube (AR = 3.0) clusters, AR = 5.2	2

Nozzle	Description	Page
HM-AP-48	49 RC tubes arranged in 7-tube (AR=3.0) clusters, AR = 6.5	2
HM-AP-49	49 tubes (12 spoke ends) arranged in 7-tube (AR = 3.0) clusters, AR = 6.5	2
HM-AP-50	49 RC tubes arranged in 7-tube (AR = 4.0) clusters, AR = 6.5	2
HM-AP-51	49 tubes (12 spoke ends) arranged in 7-tube (AR = 4.0) clusters, AR = 6.5	2
HM-AP-52	49 RC tubes arranged in 7-tube (AR = 3.0) clusters, AR = 7.8	2
HM-AP-53	49 tubes (12 spoke ends) arranged in 7-tube (AR = 3.0) clusters, AR = 7.8	2
HM-AP-54	24 spokes (air-cooled, 3,000°F), AR = 2.0	3
HM-AP-55A	37-tube hexagonal array (3,000°F), AR = 4.0	3
HM-AP-55B	37-tube hexagonal array (3,000°F), AR = 5.2	3
HM-AP-55C	37-tube hexagonal array (3,000°F), AR = 3.3	D203
HM-AP-56	37 tubes, internally ventilated, AR = 4.0	D213 2
HM-AP-57	12 spokes, AR = 1.86	D214
HM-AP-58A	42 tubes, 6 clusters of 7 tubes each, AR = 9.7	D225
HM-AP-59A	42-tube (12 spoke ends) annular array, AR = 8.3	D232
HM-AP-59B	42-tube (12 spoke and RC ends) annular array, AR = 8.3	D239
HM-AP-60	24 spokes, AR = 2.0	D246
HM-AP-61A	42 tubes, 6 clusters of 7 tubes each, and 24-spoke nozzle in the center, AR = 5.2	D254
HM-AP-64A	42-tube (12 spoke ends) annular array and 24-spoke nozzle in the center, AR = 4.4	D261
HM-AP-65A	42-tube (12 spoke ends) annular array and 4.1-in. RC nozzle in the center, AR = 4.4	D268
HM-AP-66	42-tube annular array and 3.0-in. RC central nozzle	3
HM-AP-78	16 spokes and 16 clusters of tubes, AR = 3.1	D275
HM-AP-79	49-tube array, AR = 4.0	2
HM-AP-80	49-tube (12 spoke ends) array, AR = 4.0	2
HM-AP-81-1	36-tube rectangular (6 x 6) array, AR = 3.45	2
HM-AP-81-2	36-tube rectangular (6 x 6) array, AR = 5.4	2
HM-AP-81-3	36-tube rectangular (6 x 6) array, AR = 8.2	3
HM-AP-82-1	36-tube rectangular (4 x 9) array, AR = 3.4	2
HM-AP-82-2	36-tube rectangular (4 x 9) array, AR = 5.4	2
HM-AP-82-3	36-tube rectangular (4 x 9) array, AR = 8.2	3
HM-AP-[illegible]3-1	36-tube rectangular (2 x 18) array, AR = 3.4	3
HM-AP-[illegible]	36-tube rectangular (2 x 18) array, AR = 5.4	3
HM-AP-83-[illegible]	36-tube rectangular (2 x 18) array, AR = 8.2	3
HM-AP-85-1	126-tube hexagonal array, AR = 3.33	D278 3

Nozzle	Description	Page
HM-AP-85-2	126-tube hexagonal array, AR = 5.2	D287 4
HM-AP-85-4	126-tube hexagonal array, AR = 2.8	D289 4
HM-AP-86-1	330-tube hexagonal array, AR = 4.0	D292
HM-AP-86-2	330-tube hexagonal array, AR = 5.2	D297
MAE 4A	12 spokes with plug, AR = 2.9	D301
MAE 203-3	20 spokes, AR = 2.2	D308
MPP 130-20	16 spokes, AR = 2.25	D315
MAE 53-18	24 spokes with plug, AR = 2.1	D322
MPP 152	21 tubes, AR = 2.4	D329
MPP 452	21 tubes (6 spoke ends on outer tubes), AR = 2.6	D337
253 tubes	253 tubes, AR = 4.0	D344
29xx8400	RC primary nozzle with ejector and 8 chutes	D352
97-hole plate	97 holes, AR = 2.8	D358 4
C/D nozzle	Round convergent-divergent nozzle ($A_E/A^* = 1.63$)	2
NSC 82	97 tubes, AR = 2.8 at ejector	D359 2
NSC-119B	61 tubes, AR = 2.9 at ejector	2

1 Destroyed during testing
2 Acoustic data partially analyzed
3 Needs testing
4 Measured data lost

D.2 COMPENDIUM

Descriptions of most nozzles used during the 12-20 PNdB jet noise suppression program follow. Many of these suppressor nozzles have been tested with ejectors, but the appropriate reference must be used to obtain specific information on particular configurations. The material presented here deals in particular with the noise characteristics of the primary suppressor nozzle; this represents the first stage in supersonic jet suppression.

A separate section is devoted to each nozzle. Each section provides a summary of jet noise and thrust performance characteristics from test data. The first page contains a physical description and photograph of the nozzle. Also, extrapolated perceived noise level suppression values (PNdB) as a function of jet velocity (ideal) are included. The ratio of perceived noise level suppression to the percentage of thrust loss as a function of pressure ratio is another relationship included on the first page of each section. In the SST jet noise suppression program, any ratio of ΔPNdB to Δthrust greater than unity was considered worthy of consideration, with a ratio of two considered acceptable to program goals.

The second page of a nozzle section contains further subjective acoustic data relationships: maximum perceived noise level as a function of jet velocity and perceived noise level beam patterns at the 1,500-ft. sideline. Perceived noise levels on the first and second pages

included the effect of ground-to-ground sound propagation losses. PNL suppression values vary only slightly when extra ground attenuation propagation loss is excluded from the extrapolation procedure. PNL suppression values at the 2,128-ft sideline tend to be about 1 PNdB higher than at the 1,500-ft sideline because of suppressor nozzle acoustic spectrum high-frequency emphasis and relatively higher absorption of high-frequency energy by the atmosphere.

The third page contains objective acoustic relationships in terms of measured noise levels (dB) on a 200-ft polar arc (full-scale equivalent). Suppressor nozzle radiated jet noise beam patterns (OASPL versus angle) at various pressure ratios and constant total temperature are shown. Typical octave-band spectra are also shown for three pressure ratios, nominally PR = 1.8, 2.2, and 3.0. The reference, round convergent, nozzle noise tends to peak near 50° relative to the jet axis, so these data are included in the spectral plots. Multielement suppressor nozzles tend to have maximum PNL values near 70° if jet mixing noise dominates or at 50° if jet coalescence noise dominates. These spectra were plotted to provide an indication of the relative magnitude of low-frequency jet coalescence noise and the higher-frequency jet mixing noise.

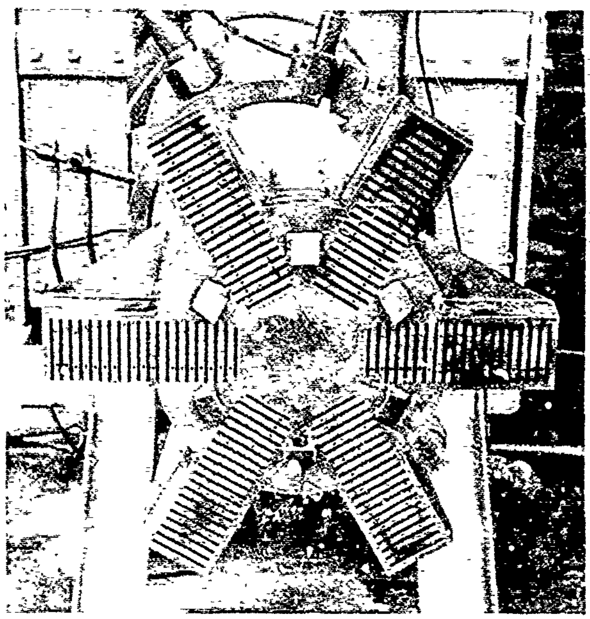
The fourth page includes some remarks about the suppressor nozzle test results, such as other configurations tested. References pertaining to test results are listed on this page.

The fifth page contains run log information for basic suppressor nozzle acoustic data. This information is to be used with measured acoustic data provided on the sixth page. Measured acoustic data are listed according to run number and angle relative to the nozzle exit and jet axis. The overall SPL, which is the integration of the eight octave bands, is given. The acoustic data are expressed in terms of actual frequencies and distances so that this information can be scaled as the user desires.

The seventh page is devoted to suppressor nozzle performance relationships. Gross thrust coefficients, discharge coefficients and base pressure ratio are shown for various pressures ratios and ventilation parameters to the extent allowed by available test data. When ejectors were tested, the nozzle-ejector data are presented.

HM-AP-6 NOZZLE

(6 LOBE, MULTI - SLOT, AR 8.28)



Description

The HM-AP-6 nozzle has 6 radial arms or lobes with 20 parallel slots per arm. Area ratio was defined as the ratio of circular area enclosed by the extreme flow boundary to the normal flow area. Slot bleed and nozzle base bleed parts of primary flow are incorporated in the nozzle design.

Number of Elements: 6 radial arms, 20 slots/arm

Area Ratio: 8.28

Flow Area: 13.2 square inches

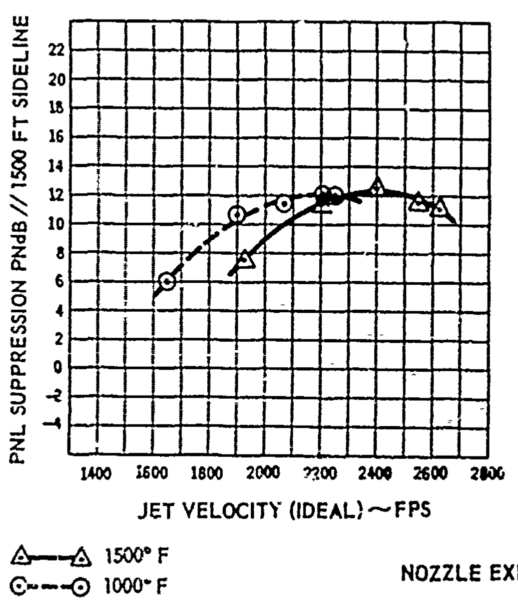
Exit Cant Angle: 0 degrees

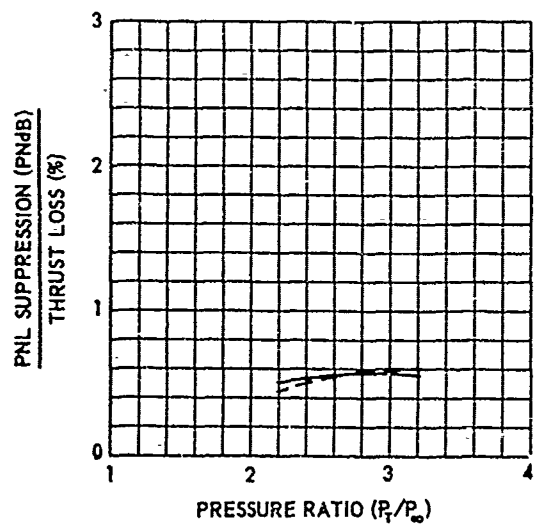
Nozzle Diameter: 11.8 inches

Slot Width: 0.075 inches

Slot Length: 1.47 inches

Base Width Between Slots: 0.15 in.

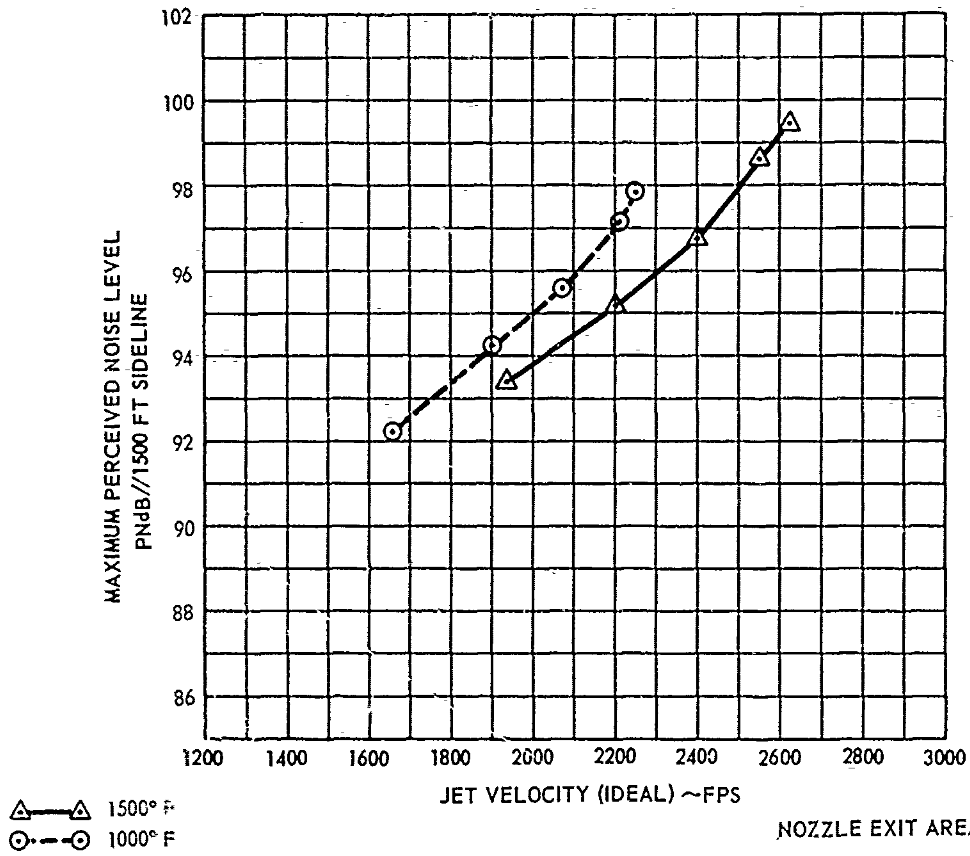




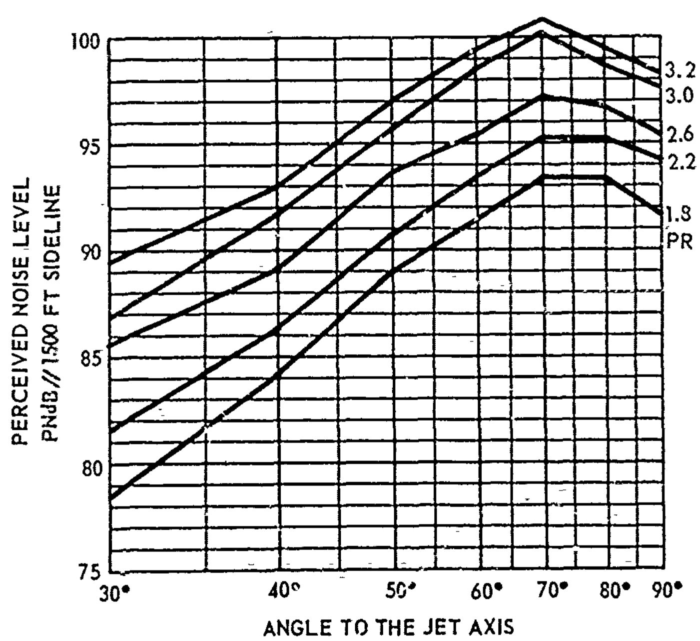
NOZZLE EXIT AREA (A_e): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM–AP–6 NOZZLE
(6 LOBE, MULTI–SLOT)
AR 8.28
SCALE FACTOR: 8:1



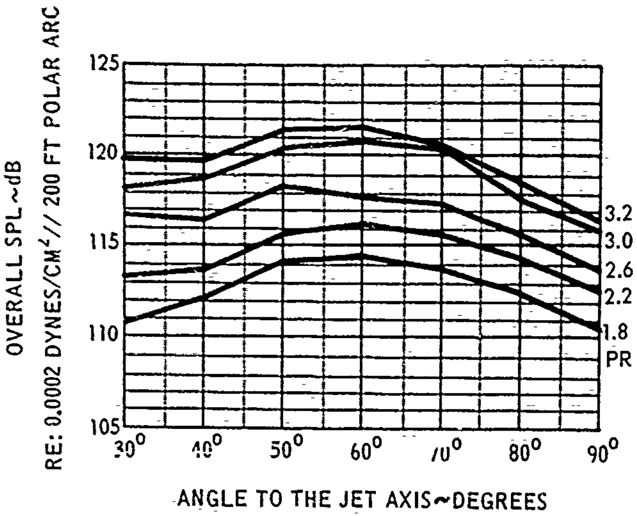
NOZZLE EXIT AREA (A_8): 5.9 FT^2



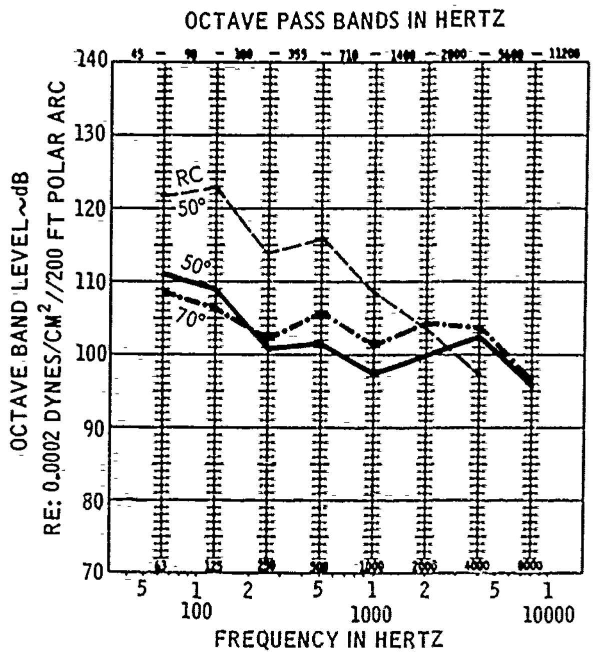
TOTAL TEMPERATURE (T_8): 1500° F

NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

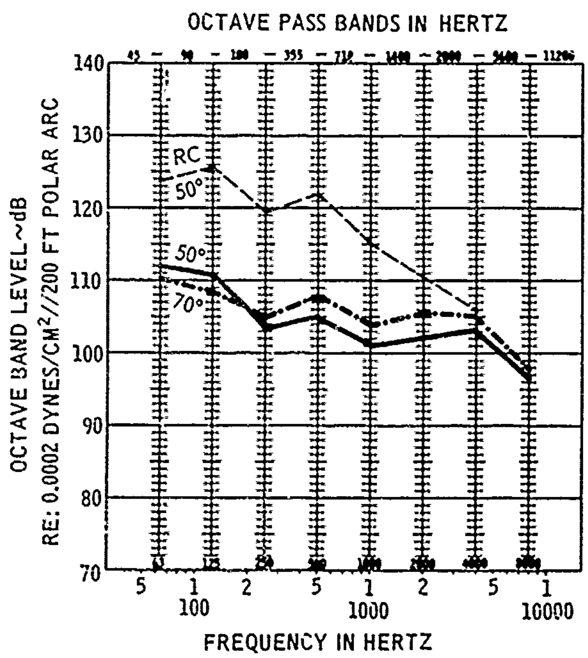


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

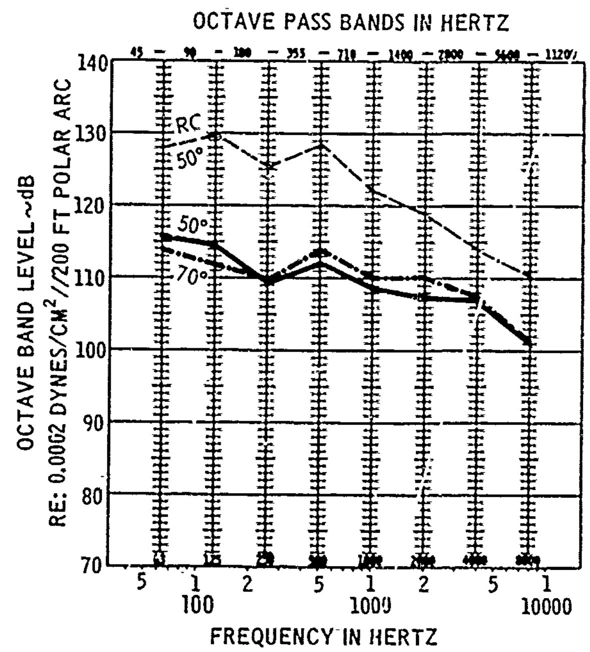


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

HM-AP-6 NOZZLE
(6 LOBE, MULTI-SLOT)
AR 8.28
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-6

(6 Lobe, Multi-slot, AR 8.28)

Remarks

The HM-AP-6 nozzle was tested with the slot bleed ports open and closed with little or no effect on noise suppression values, see Reference D1. Tests at a total temperature of 2000°F indicated a loss of suppression of about 1 PNdB compared to values attained at 1500°F.

Thrust losses were excessive.

HM-AP-6

Facility: Annex D (Cell #1)
Nozzle and microphone heights are 20 inches

Date:

T_{amb}:

R.H.:

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
H 425	1.8	1000°F	1659 fps	HM-AP-6
H 426	2.2	"	1900	"
H 427	2.6	"	2073	"
H 428	3.0	"	2205	"
H 429	3.2	"	2250	"
H 430	1.8	1500°F	1923	"
H 431	2.2	"	2202	"
H 432	2.6	"	2402	"
H 433	3.0	"	2555	"
H 434	3.2	"	2620	"
H 502	1.8	1000°F	1659 fps	4.1 Inch Round Convergent Nozzle
H 503	2.2	"	1900	"
H 504	2.6	"	2073	"
H 505	3.0	"	2205	"
H 506	3.2	"	2250	"
H 497	1.8	1500°F	1923	"
H 498	2.2	"	2202	"
H 499	2.6	"	2402	"
H 500	3.0	"	2555	"
H 501	3.2	"	2620	"

Measured acoustic data is recorded in Reference D2.

NOZZLE TEST DATA

HM-AP-6

OCTAVE BAND LEVEL ~ dB RE: 0.0002 DYNES/CM²/25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H425L30	110.0	107.8	102.4	97.6	95.2	93.8	94.8	98.2	93.5
H425L40	111.2	108.3	105.7	97.1	97.3	95.5	95.6	99.0	94.6
H425L50	112.8	109.1	107.3	99.1	100.2	96.6	99.8	102.4	95.5
H425L60	112.5	108.6	106.8	100.1	101.5	98.1	99.4	101.1	96.2
H425L70	112.3	106.7	104.2	100.0	103.4	100.[illegible]	104.0	103.6	96.3
H425L80	110.9	104.8	100.8	97.7	101.3	99.9	103.0	104.5	96.0
H425L90	108.7	101.9	101.1	98.0	99.4	98.8	99.9	100.3	94.1
H426L30	112.3	109.3	105.0	101.3	100.5	98.1	98.1	100.4	96.0
H426L40	113.1	109.4	107.3	100.4	101.9	99.6	99.1	101.2	97.0
H426L50	115.2	110.8	109.9	102.6	104.8	100.9	102.6	104.4	98.0
H426L60	114.3	109.8	108.2	102.5	105.1	101.7	102.1	102.6	97.7
H426L70	114.1	107.8	105.8	102.2	106.1	103.1	105.9	105.2	98.5
H426L80	112.8	105.7	102.0	99.8	103.9	102.5	105.4	106.4	98.1
H426L90	110.6	102.8	101.9	100.1	101.9	101.6	102.7	102.4	96.4
H427L30	113.8	110.3	106.3	104.2	103.4	100.8	100.1	101.3	96.6
H427L40	114.8	110.6	108.8	103.6	105.5	102.8	101.6	102.0	97.5
H427L50	116.3	111.8	110.7	104.2	106.4	103.5	104.3	105.0	98.6
H427L60	116.1	111.3	109.8	104.6	107.9	104.7	104.4	103.9	98.8
H427L70	115.5	109.3	107.4	104.1	108.0	105.1	106.9	105.9	99.4
H427L80	114.3	107.0	103.6	101.7	106.3	104.9	106.6	107.3	99.0
H427L90	112.2	104.0	103.0	101.6	103.8	103.5	105.0	103.9	97.4
H428L30	116.0	112.1	108.1	106.6	107.9	104.2	102.7	102.4	97.5
H428L40	116.8	112.2	110.1	106.3	109.0	105.8	104.0	103.1	98.4
H428L50	118.1	113.3	112.2	106.6	109.6	105.6	105.9	106.1	99.4
H428L60	118.0	112.7	111.3	107.0	110.8	107.6	106.4	104.7	99.4
H428L70	117.1	110.5	108.8	106.1	110.3	107.4	108.3	106.4	99.8
H428L80	115.5	108.0	104.8	103.4	108.2	106.9	107.7	107.6	99.5
H428L90	113.6	105.4	104.2	103.4	105.9	105.5	105.8	104.6	98.1
H429L30	118.1	113.9	110.1	108.7	110.5	107.0	104.7	104.0	100.5
H429L40	118.9	113.8	112.0	108.4	111.5	108.3	107.1	105.6	101.8
H429L50	119.9	114.8	114.0	108.8	111.9	108.1	107.9	107.2	102.6
H429L60	118.8	113.1	112.1	108.1	111.8	108.5	107.2	106.2	99.6
H429L70	117.8	111.1	109.5	106.9	111.5	108.3	108.9	106.5	99.9
H429L80	115.9	108.5	105.7	104.3	108.7	107.3	107.8	107.7	99.7
H429L90	114.1	105.8	104.9	104.1	106.8	105.8	106.2	104.7	98.7
H430L30	110.8	108.5	103.5	98.7	96.7	94.5	96.7	97.9	93.2
H430L40	112.2	109.3	106.1	98.8	98.9	96.5	98.4	100.4	95.0
H430L50	114.1	110.6	108.9	100.5	101.3	97.6	100.1	102.6	95.7
H430L60	114.3	110.3	108.6	102.5	104.8	100.1	101.5	101.7	96.5
H430L70	113.9	108.6	106.5	102.7	105.9	101.4	104.2	103.8	96.4
H430L80	112.5	106.6	103.0	100.4	103.5	101.4	103.7	105.2	96.5
H430L90	110.5	104.0	102.9	100.2	101.3	100.1	101.8	101.6	94.7
H431L30	113.1	109.8	107.2	102.5	101.1	98.4	97.6	99.2	94.8
H431L40	113.8	110.3	107.3	102.1	103.2	100.5	100.8	101.6	95.8
H431L50	115.7	111.9	110.4	103.2	104.8	101.1	102.1	103.4	96.6
H431L60	114.2	111.8	110.3	104.8	107.6	103.4	103.4	102.4	97.2
H431L70	115.6	110.2	108.3	105.0	108.8	104.1	105.3	104.7	97.7
H431L80	114.2	108.1	104.7	102.4	106.1	104.0	105.5	106.2	97.5
H431L90	112.6	105.5	104.6	102.6	104.2	103.2	104.4	103.1	95.9
H432L30	116.7	113.2	109.4	107.5	106.9	104.2	102.3	103.0	99.1
H432L40	116.5	112.5	110.1	105.9	107.5	104.8	104.3	98.2	100.[illegible]
H432L50	118.4	114.1	112.7	106.3	109.1	105.2	105.1	105.6	100.[illegible]
H432L60	117.9	113.1	111.8	107.2	109.8	106.3	105.4	103.5	[illegible]
H432L70	117.2	111.5	109.8	107.1	110.7	106.3	107.	105.5	98.6
H432L80	115.8	109.1	106.1	104.4	108.7	106.5	107.1	107.0	98.6
H432L90	113.8	106.1	104.9	104.0	106.0	105.1	105.8	104.1	97.2

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

HM–AP–6

OCTAVE BAND LEVEL ~ dB RE: 0.0002 DYNES/CM^2/25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H433L30	118.1	114.2	110.0	108.7	110.2	106.4	104.1	103.2	99.8
H433L40	118.9	114.1	111.8	108.8	111.3	108.1	106.6	105.1	100.2
H433L50	120.3	115.6	114.3	109.5	112.3	108.3	107.6	106.8	100.7
H433L60	120.8	115.7	114.3	110.2	113.6	110.0	108.2	106.1	102.5
H433L70	120.2	114.0	112.2	109.8	114.1	110.0	110.1	107.2	101.2
H433L80	117.8	111.4	107.9	106.3	111.1	109.1	108.8	108.2	101.5
H433L90	116.0	108.4	106.9	106.3	108.4	107.7	107.9	105.5	99.6

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

HM-AP-6

OCTAVE BAND LEVEL ~ dB RE: 0.0002 DYNES/CM^2//25 FT

RUN NO	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H434L30	119.8	115.0	111.3	110.1	113.9	108.7	105.7	103.9	100.0
H434L40	[illegible]	114.2	112.6	109.6	112.8	109.5	107.7	105.6	101.2
H434L50	121.3	116.3	115.0	110.9	113.9	109.9	109.1	107.5	101.4
H434L60	121.5	116.3	115.0	111.1	114.6	111.0	109.0	106.3	102.4
H434L70	120.8	114.4	112.6	110.5	115.0	111.0	110.9	107.3	101.4
H434L80	118.5	111.8	108.5	107.3	112.0	110.1	109.3	108.3	101.5
H434L90	116.6	108.9	107.4	107.1	109.2	108.5	108.5	105.7	99.7
H502L30	[illegible]	122.3	123.6	115.0	115.1	105.5	100.1	94.7	0.0
H502L40	[illegible]	122.5	122.7	113.5	115.5	107.3	101.5	94.7	0.0
H502L50	[illegible]	[illegible]	120.8	111.9	114.7	107.8	103.0	97.8	0.0
H502L60	120.5	115.9	115.9	109.5	112.5	106.8	102.3	97.2	0.0
H502L70	[illegible]	112.0	111.4	107.4	111.1	106.2	102.5	96.1	0.0
H502L80	112.6	106.4	105.9	104.3	106.3	[illegible]	98.5	94.0	0.0
H502L90	111.0	103.3	105.6	103.6	104.4	100.9	97.1	91.3	0.0
H503L30	130.6	125.5	126.6	120.2	122.9	113.8	109.8	106.7	0.0
H503L40	131.2	125.7	127.5	120.0	123.3	115.9	111.6	105.9	0.0
H503L50	129.2	124.4	125.5	117.4	120.4	113.7	110.0	105.6	0.0
H503L60	124.7	119.3	120.5	113.6	117.3	111.2	107.6	102.4	0.0
H503L70	120.8	114.6	114.9	110.4	115.0	110.3	107.7	101.4	0.0
H503L80	116.2	109.2	109.5	107.3	110.3	106.9	104.3	100.4	0.0
H503L90	114.6	106.2	108.4	106.6	108.6	105.8	102.1	96.6	0.0
H504L30	132.3	127.4	128.1	122.2	124.4	116.6	113.3	110.1	0.0
H504L40	133.6	127.6	129.5	123.3	126.6	119.6	115.4	110.6	0.0
H504L50	132.0	126.6	127.9	[illegible]	124.5	118.5	114.5	110.7	0.0
H504L60	127.5	121.9	122.7	116.5	120.8	115.6	112.4	107.8	101.7
H504L70	124.3	116.9	117.4	113.9	118.9	115.6	113.7	106.9	100.9
H504L80	120.1	111.1	111.6	111.0	114.5	113.1	109.7	105.6	99.1
H504L90	119.1	108.2	110.6	110.2	114.1	112.3	108.7	102.2	96.6
H505L30	133.2	129.0	[illegible]	123.6	124.1	117.0	112.8	110.0	0.0
H505L40	135.0	129.0	130.9	125.0	128.0	121.4	117.2	112.0	109.3
H505L50	134.2	128.6	129.5	124.2	127.4	121.2	117.5	113.3	108.8
H505L60	129.6	123.6	124.6	119.6	122.6	118.4	114.7	111.1	0.0
H505L70	126.6	118.8	119.2	117.2	120.7	118.7	116.1	110.7	0.0
H505L80	122.9	112.2	112.9	114.3	117.5	116.8	112.6	109.1	102.5
H505L90	[illegible]	109.5	112.1	114.0	119.1	115.3	112.3	106.1	100.7
H506L30	133.9	129.3	129.5	124.7	124.0	117.1	113.1	110.3	0.0
H506L40	135.6	129.7	131.8	125.4	128.0	121.4	117.2	112.2	108.2
H506L50	134.9	129.3	130.0	125.0	128.3	122.2	118.8	114.5	110.1
H506L60	130.2	124.3	125.2	119.9	123.1	119.0	115.0	112.2	0.0
H506L70	127.6	119.2	120.0	118.4	121.7	119.9	117.4	112.1	107.8
H506L80	124.2	112.8	113.5	115.6	119.0	118.1	[illegible]	110.5	104.2
H506L90	124.2	110.1	112.6	116.0	120.5	116.8	113.8	107.9	102.2
H497L30	127.5	122.1	124.7	118.0	115.1	107.9	102.7	98.0	0.0
H497L40	128.8	123.2	126.1	118.1	117.6	110.2	104.6	98.9	0.0
H497L50	126.1	121.5	122.7	114.1	116.0	[illegible]	103.8	97.5	0.0
H497L60	123.9	118.4	119.9	113.1	116.4	110.0	104.6	99.9	0.0
H497L70	118.5	112.8	112.8	108.3	112.8	107.0	103.3	96.4	0.0
H497L80	114.2	107.5	108.1	105.0	108.8	103.4	99.4	93.9	[illegible]
H498L30	129.5	124.9	125.1	121.8	118.4	113.8	108.8	103.9	0.0
H498L40	131.7	125.1	128.4	122.8	123.2	117.0	111.5	106.6	0.0
H498L50	129.6	123.7	125.8	119.5	122.0	114.9	110.8	105.9	0.0
H498L60	126.5	119.7	122.2	116.7	120.3	113.8	109.8	105.3	0.0
H498L70	[illegible]	114.7	115.8	[illegible]	117.0	111.8	109.3	102.1	0.0
H498L80	117.8	109.5	110.8	109.1	113.2	108.2	104.9	100.4	0.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

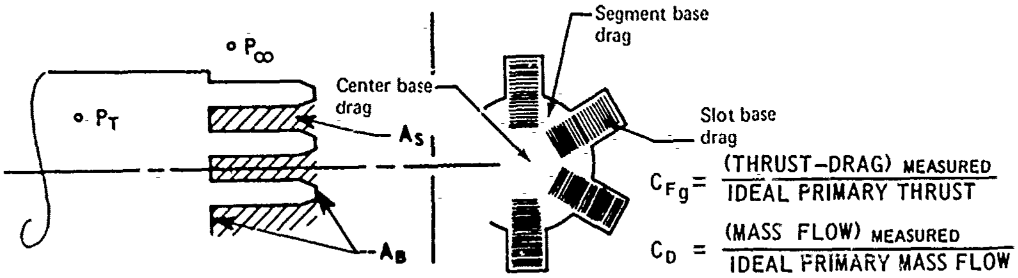
HM-AP-6

OCTAVE BAND LEVEL ~ dB RE: 0.0002 DYNES/CM^2//25 FT

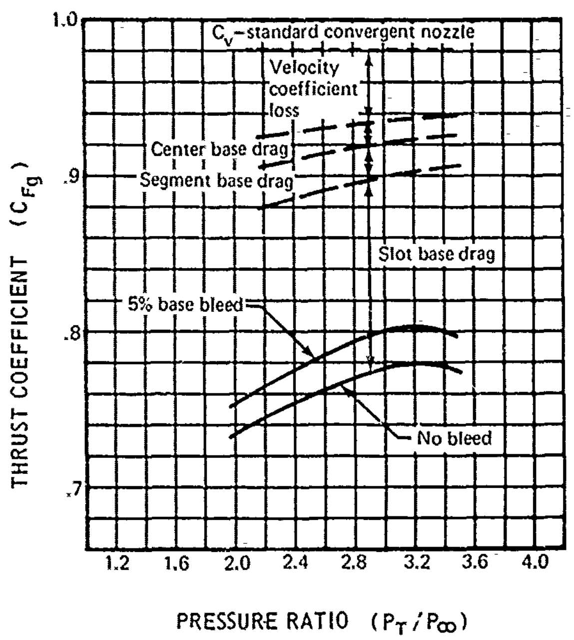
RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H499L30	130.9	126.7	126.4	121.8	120.8	115.3	111.7	107.4	0.0
H499L40	134.7	128.1	131.0	126.3	126.4	121.2	116.3	111.8	107.7
H499L50	132.7	126.2	128.0	123.5	126.4	119.6	116.3	111.6	0.0
H499L60	130.4	122.5	125.3	120.9	125.1	119.2	114.8	111.4	0.0
H499L70	124.9	116.3	118.2	115.5	120.1	115.6	113.6	107.8	0.0
H499L80	120.1	113.5	110.8	110.4	115.0	111.7	108.5	103.8	98.5
H500L30	132.1	128.5	127.3	122.6	121.3	115.8	111.7	107.5	0.0
H500L40	135.0	128.8	131.4	125.6	126.5	120.7	116.5	111.8	107.7
H500L50	134.6	127.8	129.7	125.5	128.7	122.1	119.2	114.1	110.5
H500L60	131.6	123.7	126.1	125.3	126.6	120.4	116.5	112.8	107.8
H500L70	127.4	118.3	119.8	118.4	122.3	119.1	116.8	111.6	107.3
H500L80	124.7	116.1	114.4	115.4	119.9	117.8	113.8	109.4	103.4
H501L30	133.3	130.0	128.1	123.9	122.5	116.8	113.2	108.6	0.0
H501L40	136.0	130.0	132.4	126.6	127.4	121.5	117.0	112.7	108.4
H501L50	135.5	128.9	130.5	126.7	129.4	122.8	119.7	114.7	111.0
H501L60	133.4	125.5	127.9	124.4	128.3	122.1	118.2	114.4	109.2
H501L70	128.6	119.6	121.6	119.9	123.0	119.9	117.7	112.1	107.8
H501L80	125.6	114.4	116.0	116.7	121.2	118.6	114.7	111.4	107.1

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

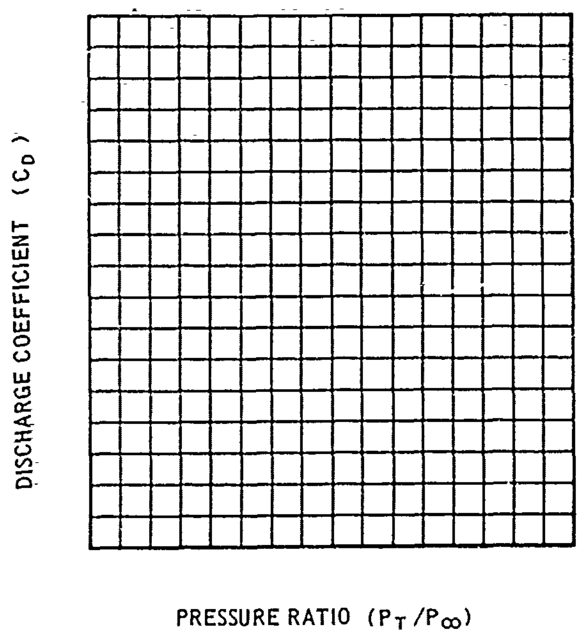
HM-AP-6



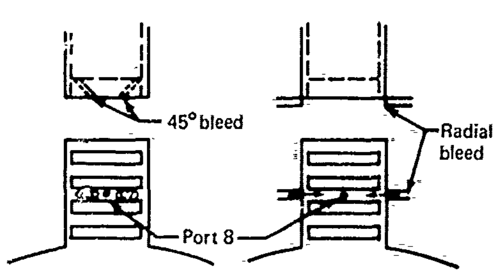
P_∞
P_T
Center base drag
A_S
A_B
Segment base drag
Slot base drag
$C_{Fg} = \frac{\text{(THRUST–DRAG) MEASURED}}{\text{IDEAL PRIMARY THRUST}}$
$C_D = \frac{\text{(MASS FLOW) MEASURED}}{\text{IDEAL PRIMARY MASS FLOW}}$



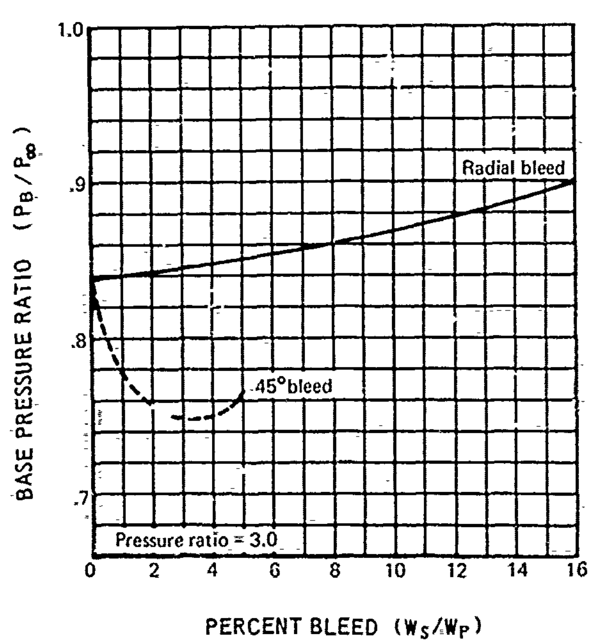
C_v–standard convergent nozzle
Velocity coefficient loss
Center base drag
Segment base drag
Slot base drag
5% base bleed
No bleed
THRUST COEFFICIENT (C_{Fg})
1.0
.9
.8
.7
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
PRESSURE RATIO (P_T/P_∞)



DISCHARGE COEFFICIENT (C_D)
PRESSURE RATIO (P_T/P_∞)



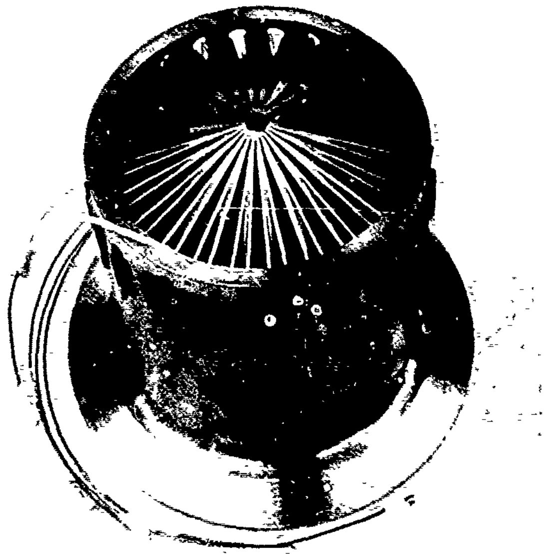
45° bleed
Radial bleed
Port 8



BASE PRESSURE RATIO (P_B/P_∞)
1.0
.9
.8
.7
Radial bleed
45° bleed
Pressure ratio = 3.0
0
2
4
6
8
10
12
14
16
PERCENT BLEED (W_S/W_P)

HM-AP-9 NOZZLE

(24SPOKES AR1.9)



Description

Number of Elements: 24 spokes

Area Ratio: 1.9

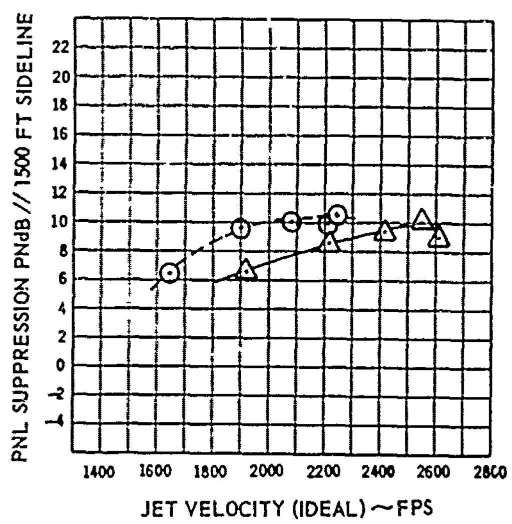
Spoke Penetration: 95%

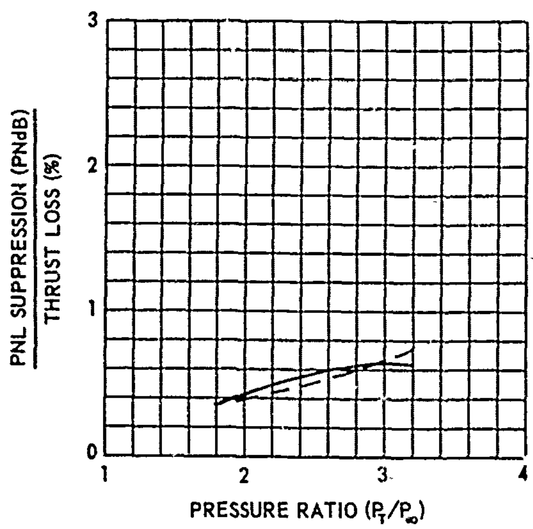
Flow Area: 13.2 square inches

Exit Cant Angle: 17.5 degrees (outward)

Ventilation Gutter Cant Angle: 30 degrees

Nozzle Diameter: 5.66 inches (flow)

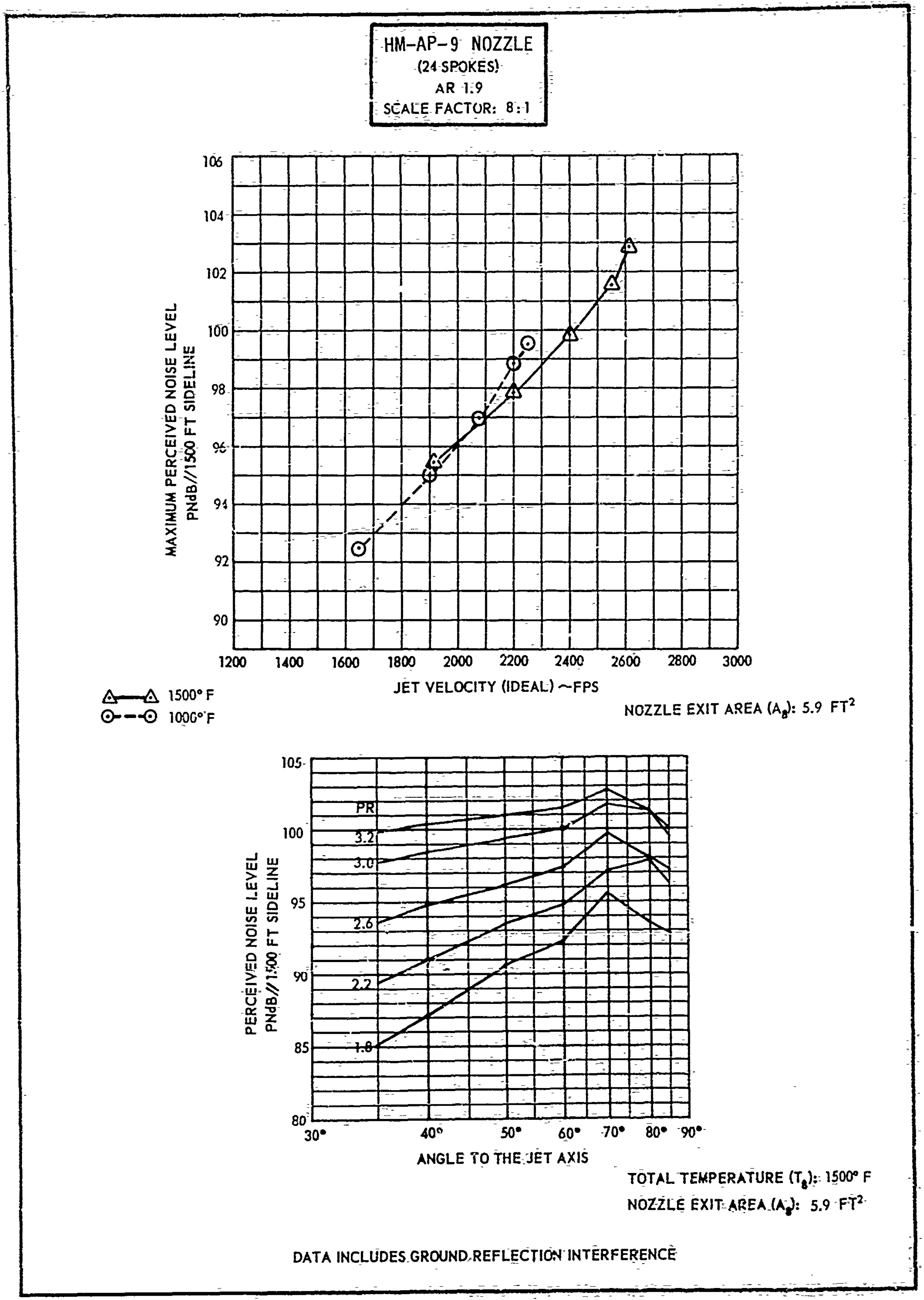




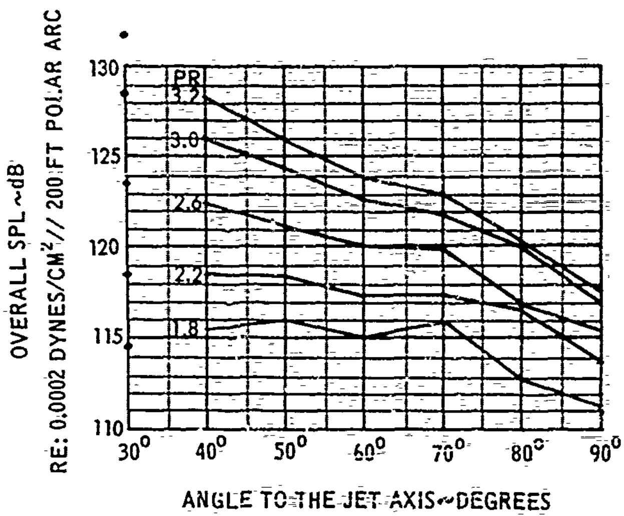
△—△ 1500° F
⊙---⊙ 1000° F

NOZZLE EXIT AREA (A_8): 5.9 FT^2

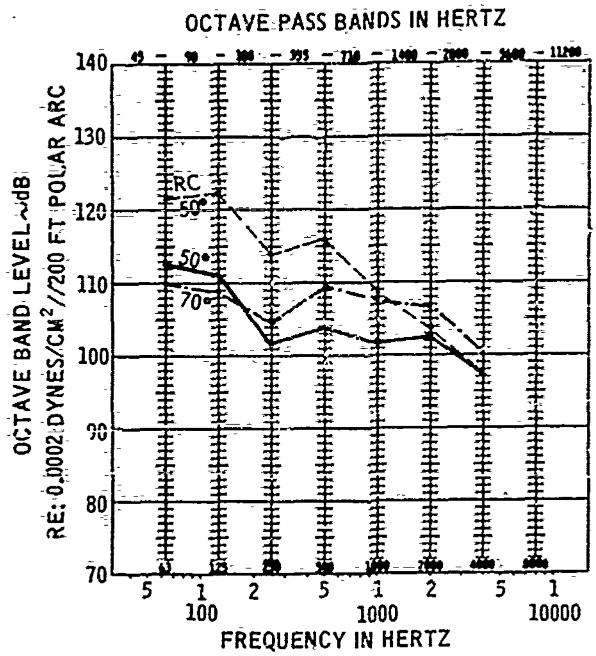
DATA INCLUDES GROUND REFLECTION INTERFERENCE



HM-AP-9 NOZZLE
(24 SPOKES)
AR 1.9
SCALE FACTOR: 8:1
MAXIMUM PERCEIVED NOISE LEVEL
PNdB//1500 FT SIDELINE
106
104
102
100
98
96
94
92
90
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
JET VELOCITY (IDEAL) ~FPS
1500° F
1000° F
NOZZLE EXIT AREA (A_8): 5.9 FT^2
PERCEIVED NOISE LEVEL
PNdB//1500 FT SIDELINE
PR
3.2
3.0
2.6
2.2
1.8
105
100
95
90
85
80
30°
40°
50°
60°
70°
80°
90°
ANGLE TO THE JET AXIS
TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT^2
DATA INCLUDES GROUND REFLECTION INTERFERENCE

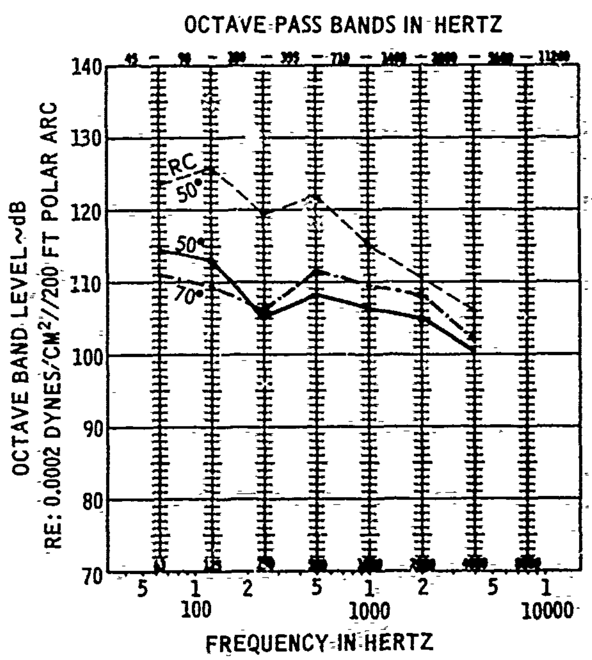


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

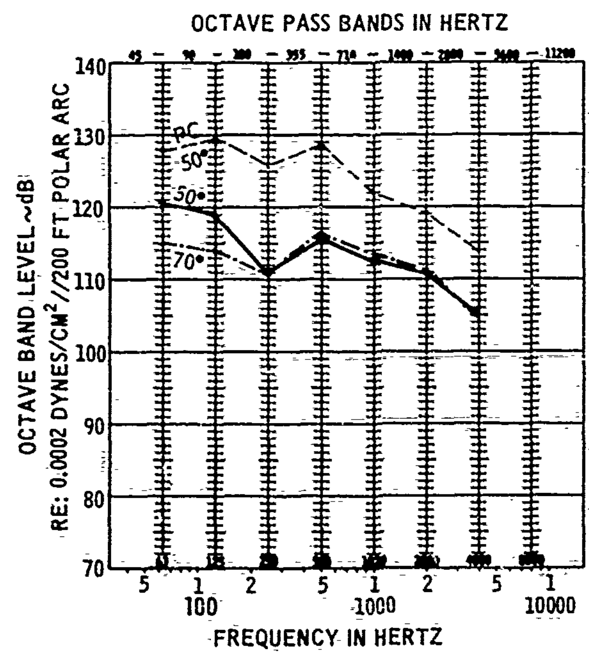


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

HM-AP-9 NOZZLE
(24 SPOKES)
AR 1.9
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-9

(24 Spokes, AR 1.9)

Remarks

An addition of a short ejector with a diameter equal to the flow diameter resulted in reduced PNL suppression values, see Reference D1. PNL suppression values attained at T_T = 2000°F were approximately the same as those at T_T = 1500°F.

HM-AP-9

Facility: Annex D (Cell #1)
Nozzle and microphone heights are 20 inches

Date:

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H 452	1.8	1000°F	1659 fps	HM-AP-9
H 453	2.2	"	1900	"
H 454	2.6	"	2073	"
H 455	3.0	"	2205	"
H 456	3.2	"	2250	"
H 457	1.8	1500°F	1923	"
H 458	2.2	"	2202	"
H 459	2.6	"	2402	"
H 460	3.0	"	2555	"
H 461	3.2	"	2620	"
H 502	1.8	1000°F	1659 fps	4.1 Inch Round Convergent Nozzle
H 503	2.2	"	1900	"
H 504	2.6	"	2073	"
H 505	3.0	"	2205	"
H 506	3.2	"	2250	"
H 497	1.8	1500°F	1923	"
H 498	2.2	"	2202	"
H 499	2.6	"	2402	"
H 500	3.0	"	2555	"
H 501	3.2	"	2620	"

Measured acoustic data is recorded in Reference D2.

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM²//25 FT

HM-AP-9

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H452L30	113.7	111.9	106.2	99.6	99.4	99.2	98.0	94.9	0.0
H452L40	114.6	111.9	109.2	99.6	101.8	100.8	99.8	95.4	0.0
H452L50	114.8	111.7	109.9	100.1	102.4	100.2	100.8	95.4	0.0
H452L60	114.8	110.7	109.1	101.9	106.5	102.4	102.0	97.6	89.8
H452L70	113.3	108.4	106.6	100.5	105.6	103.4	103.7	96.8	90.4
H452L80	111.1	106.1	104.2	89.2	103.5	100.7	101.1	96.2	89.9
H452L90	109.8	103.7	102.8	99.5	101.8	100.4	100.9	96.2	87.1
H453L30	116.6	114.8	108.0	103.1	103.8	104.4	100.6	96.9	0.0
H453L40	117.0	114.1	110.7	103.1	106.6	105.1	102.7	97.7	0.0
H453L50	116.9	113.5	111.3	102.8	106.6	104.6	103.9	99.9	0.0
H453L60	117.0	112.2	110.8	104.9	109.8	106.3	104.7	101.4	0.0
H453L70	115.4	109.5	108.1	103.5	108.4	106.8	106.7	100.3	0.0
H453L80	113.1	107.2	105.8	101.5	106.1	103.9	103.8	99.8	0.0
H453L90	111.7	104.5	104.1	102.1	104.4	103.1	103.0	99.9	0.0
H454L30	122.8	118.9	118.8	111.3	107.4	108.4	109.6	104.8	0.0
H454L40	120.1	116.8	114.2	106.1	110.2	109.5	106.5	100.2	0.0
H454L50	119.5	116.0	114.0	105.6	109.4	107.4	106.1	101.6	0.0
H454L60	119.2	114.5	113.0	107.3	111.7	108.6	107.3	103.3	96.4
H454L70	117.6	111.6	110.0	106.2	111.0	108.8	108.1	102.2	0.0
H454L80	115.7	109.2	108.1	105.5	109.3	106.8	105.8	102.2	0.0
H454L90	113.8	105.8	105.8	104.9	106.5	105.8	105.1	102.2	95.3
H455L30	124.4	122.8	115.3	110.0	112.8	111.5	106.1	103.1	0.0
H455L40	123.3	119.8	117.6	109.7	113.7	111.8	109.6	104.1	0.0
H455L50	122.2	118.7	116.5	108.8	112.8	109.7	108.6	103.5	0.0
H455L60	121.3	116.8	114.9	109.6	114.0	110.3	108.7	104.4	97.3
H455L70	119.0	112.8	111.9	108.0	112.6	109.6	108.8	103.3	98.2
H455L80	116.1	110.1	108.7	105.7	109.8	106.6	105.9	102.4	0.0
H455L90	114.7	106.9	107.3	105.2	108.0	105.7	105.5	102.7	95.9
H456L30	126.7	125.3	116.3	112.0	115.9	113.1	107.3	104.4	0.0
H456L40	124.8	121.1	119.1	111.6	115.7	113.4	110.9	105.0	0.0
H456L50	123.2	119.5	117.6	110.0	114.1	110.9	109.6	104.2	99.0
H456L60	122.1	117.4	116.0	110.6	114.9	111.2	109.5	105.1	98.2
H456L70	119.8	113.8	112.6	108.1	113.6	110.5	110.0	103.7	98.6
H456L80	117.1	110.5	109.8	106.7	111.1	107.6	106.6	103.2	98.6
H456L90	115.6	107.7	108.2	106.1	108.7	106.7	106.9	103.5	95.8
H457L30	114.5	112.5	107.5	101.4	100.4	100.3	98.4	95.0	0.0
H457L40	115.3	112.5	109.9	101.6	102.9	101.3	100.2	95.9	0.0
H457L50	115.9	112.7	111.1	101.8	103.8	101.7	102.6	97.2	0.0
H457L60	115.1	110.6	109.9	103.3	106.7	102.7	102.2	98.6	0.0
H457L70	116.1	110.1	108.8	104.7	109.4	107.4	106.4	100.1	0.0
H457L80	113.0	107.2	105.7	102.8	106.1	103.5	103.3	98.8	0.0
H457L90	111.3	104.2	104.3	102.6	104.1	102.2	102.1	98.0	0.0
H458L30	118.6	116.5	109.7	106.1	106.6	108.1	102.9	98.5	0.0
H458L40	118.5	114.9	112.7	105.6	108.8	108.1	104.8	98.7	0.0
H458L50	118.4	114.7	113.1	105.3	108.3	106.5	105.1	100.4	0.0
H458L60	117.4	112.3	111.6	105.7	110.0	106.8	105.3	101.3	0.0
H458L70	117.5	110.9	109.6	106.2	111.5	109.3	108.0	101.9	0.0
H458L80	116.6	108.8	107.8	106.0	110.9	108.4	107.7	103.8	98.0
H458L90	113.8	105.8	105.6	106.0	107.1	105.8	105.1	100.5	0.0
H459L30	123.6	122.0	113.5	110.2	112.4	112.0	106.3	102.0	0.0
H459L40	122.4	118.9	116.6	109.3	113.5	112.4	108.7	102.2	0.0
H459L50	121.2	117.2	115.7	107.8	112.3	110.1	107.8	102.9	0.0
H459L60	119.9	114.9	114.2	108.1	112.7	109.5	107.3	102.9	0.0
H459L70	119.8	112.9	112.0	108.6	114.2	111.1	109.9	103.7	98.6
H459L80	116.9	109.6	108.7	106.5	111.4	108.2	107.1	103.0	97.9
H459L90	115.3	106.8	107.2	106.4	109.2	107.5	106.0	102.0	0.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERENCE

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-9

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H460L30	128.6	127.5	117.9	114.9	115.9	113.8	107.8	103.5	0.0
H460L40	126.1	122.4	120.4	113.6	117.7	115.0	110.7	104.5	0.0
H460L50	124.3	120.4	119.1	111.1	115.5	112.6	110.6	104.8	0.0
H460L60	122.6	117.6	116.9	110.7	115.4	112.3	109.7	104.9	98.6
H460L70	121.8	115.1	114.2	111.3	116.2	113.2	111.1	104.6	99.5
H460L80	120.1	112.6	111.8	110.7	114.8	111.2	109.5	105.3	100.1
H460L90	116.9	108.9	108.8	108.4	110.8	108.7	106.9	103.1	95.5
H461L30	131.3	130.2	121.8	117.7	118.2	114.6	108.8	104.5	0.0
H461L40	128.4	125.1	122.5	115.0	120.3	116.2	111.0	105.7	0.0
H461L50	126.1	122.2	120.8	113.7	117.4	114.5	111.0	106.6	0.0
H461L60	124.1	118.0	118.3	112.9	117.1	113.3	111.0	106.8	0.0
H461L70	122.9	116.4	115.6	112.0	117.5	113.4	111.6	105.4	100.3
H461L80	120.2	113.2	112.5	110.5	114.7	110.8	109.1	105.2	100.2
H461L90	117.7	109.7	109.8	109.7	111.6	109.1	107.2	103.5	95.9

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERENCE

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-9

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H502L30	126.7	122.3	123.6	115.0	115.1	105.5	100.1	94.7	0.0
H502L40	126.8	122.5	123.7	113.5	115.5	107.3	101.5	94.7	0.0
H502L50	124.7	120.9	120.8	111.9	114.7	107.8	103.0	97.8	0.0
H502L60	120.5	115.9	115.9	109.5	112.5	106.8	102.3	97.2	0.0
H502L70	117.4	112.0	111.4	107.4	111.1	106.2	102.5	96.1	0.0
H502L80	112.6	106.4	105.9	104.3	106.3	102.6	98.5	94.0	0.0
H502L90	111.0	103.3	105.6	103.6	104.4	100.9	97.1	91.3	0.0
H503L30	130.6	125.5	126.6	120.2	122.9	113.8	109.8	106.7	0.0
H503L40	131.2	125.7	127.5	120.0	123.3	115.9	111.6	105.9	0.0
H503L50	129.2	124.4	125.5	117.4	120.4	113.7	110.0	105.6	0.0
H503L60	124.7	119.3	120.5	113.6	117.3	111.2	107.6	102.4	0.0
H503L70	120.8	114.6	114.9	110.4	115.0	110.3	107.7	101.4	0.0
H503L80	116.2	109.2	109.5	107.3	110.3	106.9	104.3	100.4	0.0
H503L90	114.6	106.2	108.4	106.6	108.6	105.8	102.1	96.6	0.0
H504L30	132.3	127.4	128.1	122.2	124.4	116.6	113.3	110.1	0.0
H504L40	133.6	127.6	129.5	123.3	126.6	119.6	115.4	110.6	0.0
H504L50	132.0	126.6	127.9	121.2	124.5	118.5	114.5	110.7	0.0
H504L60	127.5	121.9	122.7	116.5	120.8	115.6	112.4	107.8	101.7
H504L70	124.3	116.9	117.4	113.9	118.9	115.6	113.7	106.9	100.9
H504L80	120.1	111.1	111.6	111.0	114.5	113.1	109.7	105.6	99.1
H504L90	119.1	108.2	110.6	110.2	114.1	112.3	108.7	102.2	96.6
H505L30	133.2	129.0	128.5	123.6	124.1	117.0	112.8	110.0	0.0
H505L40	135.0	129.0	130.9	125.0	128.0	121.4	117.2	112.0	109.3
H505L50	134.2	128.6	129.5	124.2	127.4	121.2	117.5	113.3	108.8
H505L60	129.6	123.6	124.6	119.6	122.6	118.4	114.7	111.1	0.0
H505L70	126.6	118.8	119.2	117.2	120.7	118.7	116.1	110.7	0.0
H505L80	122.9	112.2	112.9	114.3	117.5	116.8	112.6	109.1	102.5
H505L90	122.7	109.5	112.1	114.0	119.1	115.3	112.3	106.1	100.7
H506L30	133.9	129.8	129.5	124.7	124.0	117.1	113.1	110.3	0.0
H506L40	135.6	129.7	131.8	125.6	128.0	121.4	117.2	112.2	109.2
H506L50	134.9	129.3	130.0	125.0	128.3	122.2	118.8	114.5	110.1
H506L60	130.2	124.3	125.2	119.9	123.1	119.0	115.9	112.2	0.0
H506L70	127.6	119.2	120.0	118.4	121.7	119.9	117.4	112.1	107.8
H506L80	124.2	112.8	113.5	115.6	119.0	118.1	113.9	110.5	104.2
H506L90	124.2	110.1	112.6	116.0	120.5	116.8	113.8	107.9	102.2
H497L30	127.5	122.1	124.7	118.0	115.1	107.8	102.7	98.9	0.0
H497L40	128.8	123.2	126.1	118.1	117.6	110.2	104.6	98.9	0.0
H497L50	126.1	121.5	122.7	114.1	116.0	108.7	103.8	97.5	0.0
H497L60	123.9	118.4	119.9	113.1	116.4	110.0	104.6	99.9	0.0
H497L70	118.5	112.8	112.8	108.3	112.8	107.0	103.3	96.4	0.0
H497L80	114.2	107.5	108.1	105.0	108.8	103.4	99.4	93.9	87.1
H498L30	129.5	124.9	125.1	121.8	118.4	113.8	108.8	103.9	0.0
H498L40	131.7	125.1	128.4	122.8	123.2	117.0	111.5	106.6	0.0
H498L50	129.6	123.7	125.9	119.5	122.0	114.9	110.8	105.9	0.0
H498L60	126.5	119.7	122.2	116.7	120.3	113.8	109.8	105.3	0.0
H498L70	122.0	114.7	115.8	112.3	117.0	111.8	109.3	102.1	0.0
H498L80	117.8	109.5	110.8	109.1	113.2	108.2	104.9	100.4	0.0
H499L30	130.9	126.7	126.4	121.8	120.8	115.3	111.7	107.4	0.0
H499L40	134.7	128.1	131.0	126.3	126.4	121.2	116.3	111.8	107.7
H499L50	132.7	126.2	128.0	123.5	126.4	119.6	116.3	111.6	0.0
H499L60	130.4	122.5	125.3	120.9	125.1	119.2	114.8	111.4	0.0
H499L70	124.9	116.3	118.2	115.5	128.1	115.6	113.6	107.8	0.0
H499L80	120.1	113.5	110.8	110.4	115.0	111.7	108.5	103.8	98.5

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

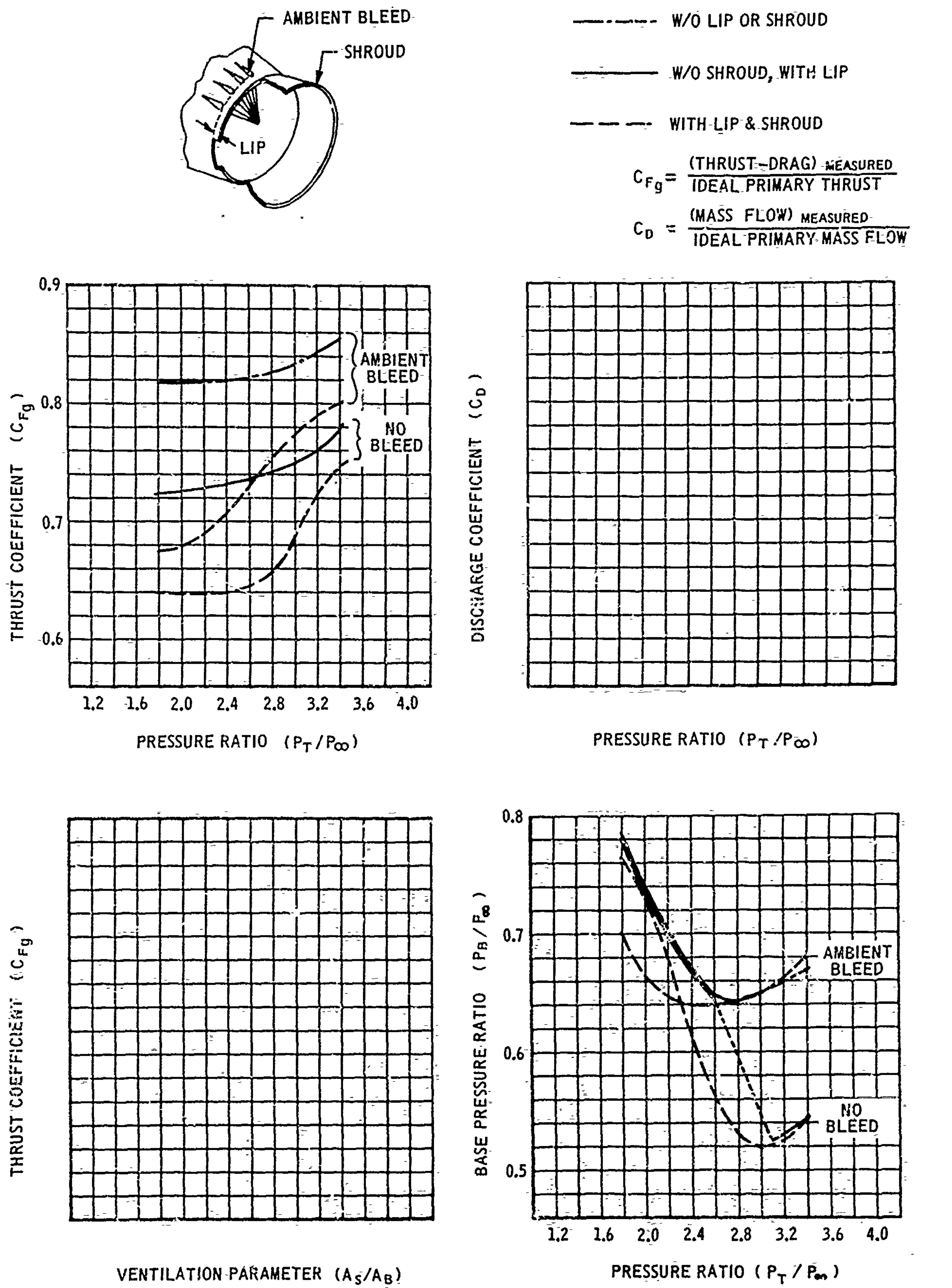
OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM²//25 FT

HM-AP-9

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H500L30	132.1	128.5	127.3	122.6	121.3	115.8	111.7	102.5	0.0
H500L40	135.0	128.8	131.4	125.6	126.5	120.7	116.5	111.8	107.7
H500L50	134.6	127.8	129.7	125.5	128.7	122.1	119.2	114.1	110.5
H500L60	131.6	123.7	126.1	122.3	126.6	120.4	116.5	112.8	107.8
H500L70	127.4	118.3	119.8	118.4	122.3	119.1	116.8	111.6	107.3
H500L80	124.7	116.1	114.4	115.4	119.9	117.8	113.8	109.4	103.4
H501L30	133.3	130.0	128.1	123.9	122.5	116.8	113.2	108.6	0.0
H501L40	136.0	130.0	132.4	126.6	127.4	121.5	117.0	112.7	108.4
H501L50	135.5	128.9	130.5	126.7	129.4	122.8	119.7	114.7	111.0
H501L60	133.4	125.5	127.9	124.4	128.3	122.1	118.2	114.4	109.2
H501L70	128.6	119.6	121.6	119.9	123.3	119.9	117.7	112.1	107.8
H501L80	125.6	114.4	116.0	116.7	121.2	118.6	114.7	111.4	107.1

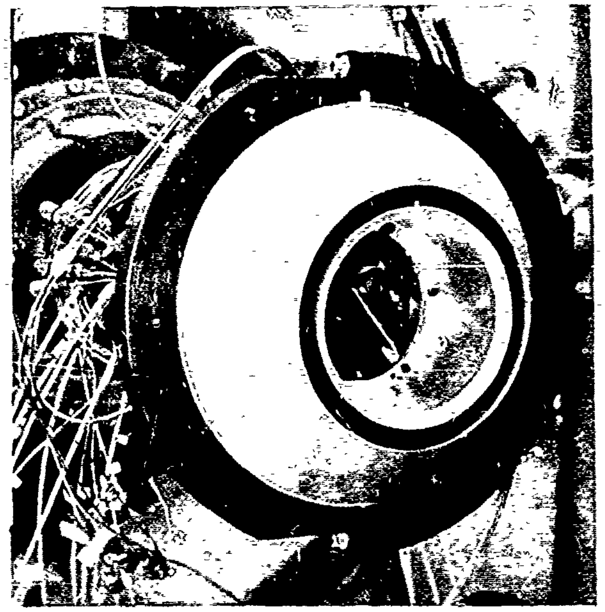
NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-9


AMBIENT BLEED
SHROUD
LIP
W/O LIP OR SHROUD
W/O SHROUD, WITH LIP
WITH LIP & SHROUD
$C_{F_g} = \frac{(\text{THRUST} - \text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$
$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$
0.9
0.8
0.7
0.6
THRUST COEFFICIENT (C_{F_g})
AMBIENT BLEED
NO BLEED
1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0
PRESSURE RATIO (P_T/P_∞)
DISCHARGE COEFFICIENT (C_D)
PRESSURE RATIO (P_T/P_∞)
THRUST COEFFICIENT (C_{F_g})
VENTILATION PARAMETER (A_S/A_B)
0.8
0.7
0.6
0.5
BASE PRESSURE RATIO (P_B/P_∞)
AMBIENT BLEED
NO BLEED
1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0
PRESSURE RATIO (P_T/P_∞)

HM-AP-12 NOZZLE

(ANNULUS, AR 4.0)



Description

The HM-AP-12 is an annulus nozzle that provides ventilation to the center base area through hollow struts. The hollow struts lead from the outside periphery of the nozzle to a hollow plug that projects into the primary flow.

Number of Elements: one annulus

Area Ratio: 4.0

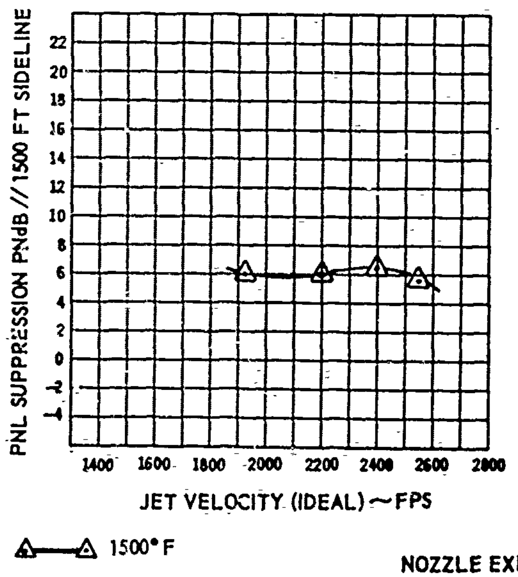
Flow Area: 13.2 square inches

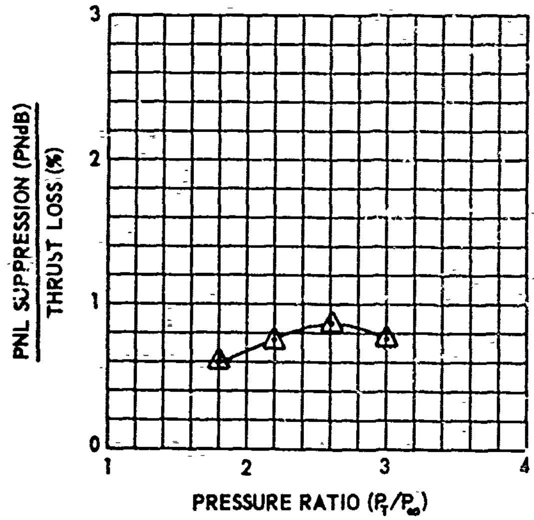
Annulus Width: 1.1 inches

Outside Diameter of Annulus: 8.2 inches

Exit Cant Angle: 0 degrees

Material: 321 CRES

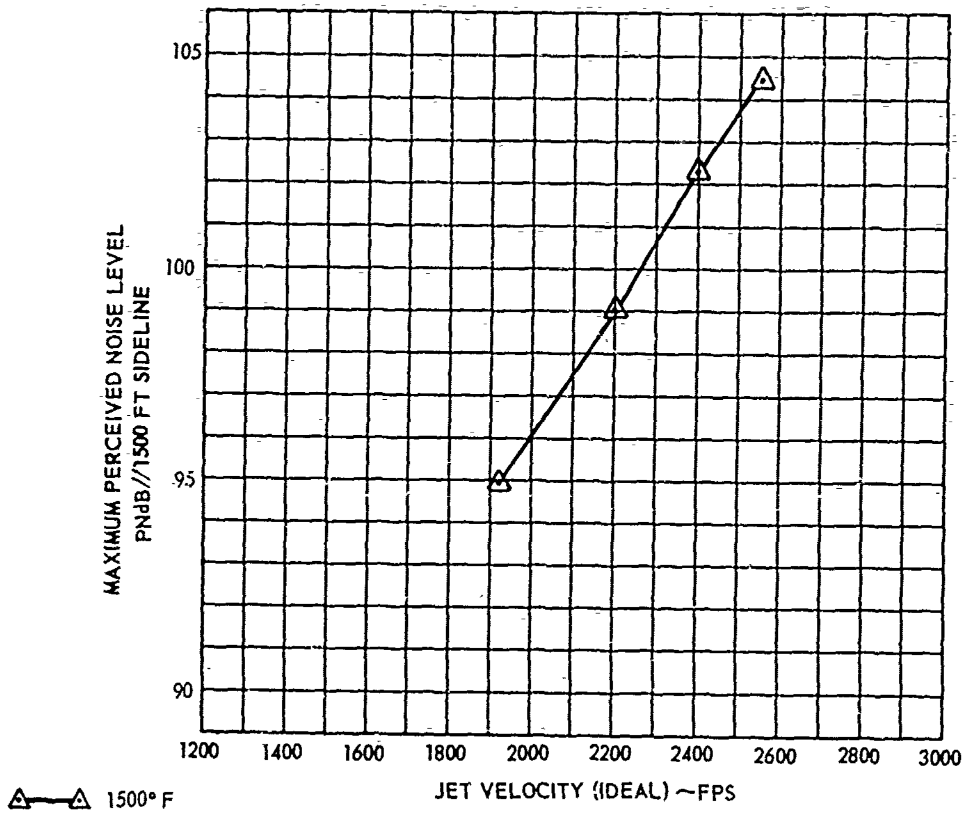




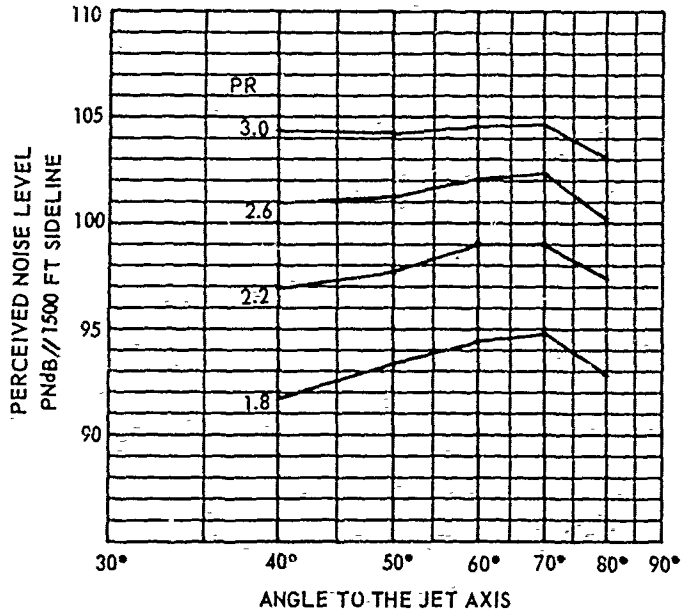
NOZZLE EXIT AREA (A_e): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-12 NOZZLE
(ANNULUS)
AR 4.0
SCALE FACTOR: 8:1

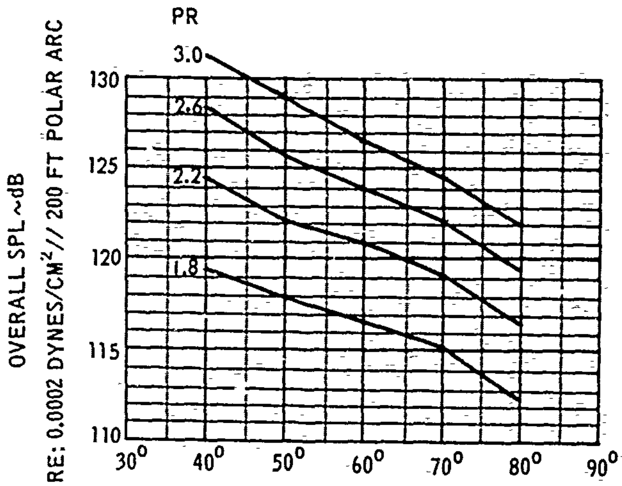


NOZZLE EXIT AREA (A_8): 5.9 FT^2

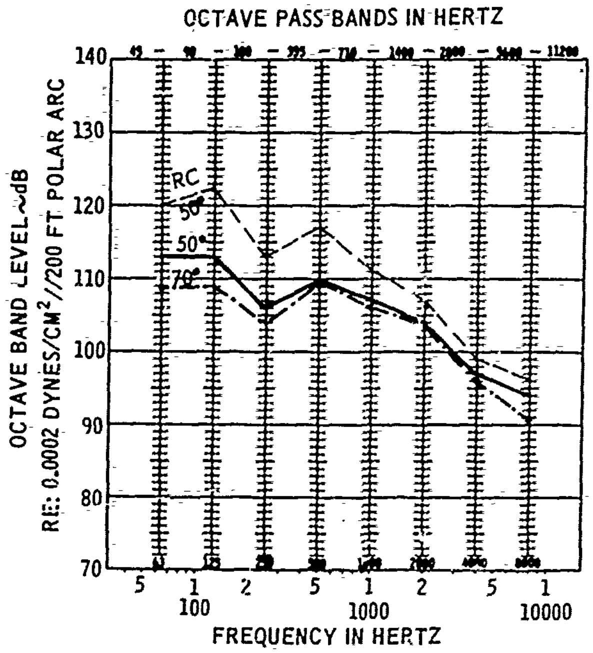


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

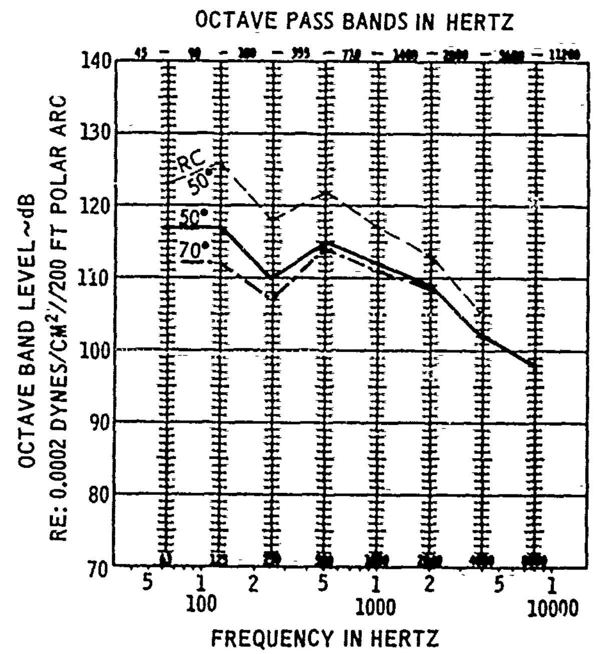


ANGLE TO THE JET AXIS~DEGREES
TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT^2

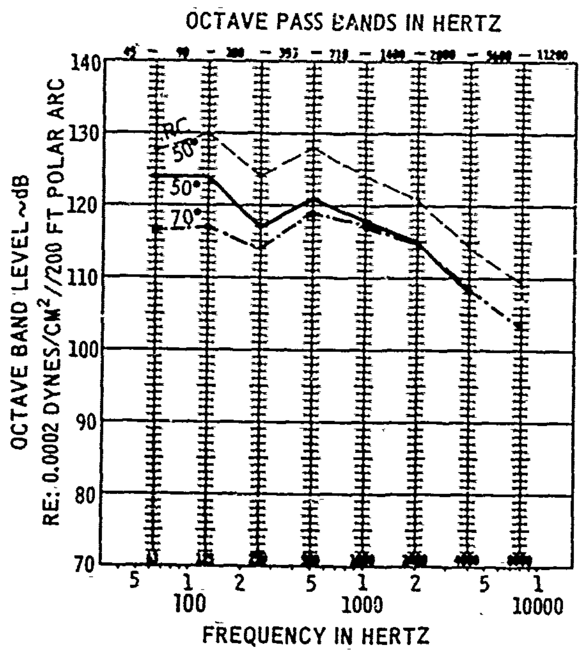


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT^2

HM-AP-12 NOZZLE
(ANNULUS)
AR 4.0
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT^2



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-12

(Annulus)

Remarks

The HM-AP-12 nozzle was tested with various hardware added downstream of the nozzle exit plane, see References D3, D4 & D5. The configurations tested were:

(a) Pure Annulus with ventilation to the center region.

(b) Pure Annulus with 11.4" diameter ejector.

(c) Pure Annulus with 11.4" diameter ejector and 100% penetration of the jet with chutes.

(d) Pure Annulus with cylindrical centerbody.

(e) Pure Annulus with cylindrical centerbody and 11.4" diameter ejector with 100% penetration with chutes.

(f) Pure Annulus with cylindrical centerbody and 11.4" diameter ejector.

(g) Pure Annulus with cylindrical centerbody and 10.5" diameter ejector and 100% penetration with chutes.

(h) Pure Annulus with cylindrical centerbody and 10.8" diameter ejector with 100% penetration with chutes.

HM-AP-12

Facility: Annex D (Cell #1)
Nozzle and microphone heights are 20 inches.

Date:

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_j (Ideal)	Nozzle
H 776	1.8	1500°F	1923 fps	HM-AP-12
H 777	2.2	"	2202	"
H 778	2.6	"	2402	"
H 779	3.0	"	2555	"
H 841	1.8	1500°F	1923 fps	4.1 Inch Round Convergent Nozzle
H 842	2.2	"	2202	"
H 843	2.6	"	2402	"
H 844	3.0	"	2555	"

Measured acoustic data is recorded in Reference D2.

NOZZLE TEST DATA

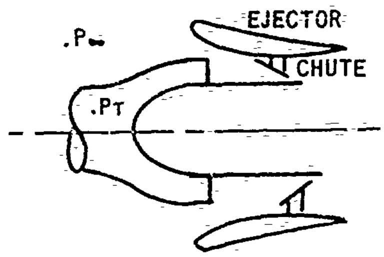
OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-12

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H776L40	119.3	115.0	114.0	106.0	111.0	109.0	104.0	96.0	-0.0
H776L50	117.9	113.0	113.0	106.0	110.0	107.0	104.0	97.0	94.0
H776L60	116.7	111.0	111.0	105.0	110.0	107.0	104.0	98.0	91.0
H776L70	115.2	108.5	109.0	104.0	109.5	106.0	103.5	96.0	90.5
H776L80	112.4	106.0	106.0	102.0	106.0	104.0	100.5	93.0	88.0
H777L40	124.5	120.5	119.0	110.0	116.0	114.0	110.0	102.0	97.0
H777L50	122.2	117.0	117.0	110.0	115.0	112.0	109.0	102.0	98.0
H777L60	121.0	115.0	115.0	109.0	115.0	111.0	109.0	103.0	97.5
H777L70	119.2	112.0	112.0	107.0	116.0	111.0	109.0	102.0	-0.0
H777L80	116.4	109.5	109.0	106.0	111.0	108.5	105.0	99.0	92.5
H778L40	128.4	124.0	124.0	114.0	119.0	118.0	113.0	106.0	-0.0
H778L50	125.7	120.5	121.0	113.5	118.0	115.0	112.0	105.0	101.0
H778L60	123.9	117.0	118.0	112.5	118.0	115.0	112.0	107.0	100.0
H778L70	122.2	114.0	115.0	111.0	117.0	114.0	112.0	106.0	101.0
H778L80	119.4	112.0	112.0	109.0	113.0	112.0	110.0	103.0	98.0
H779L40	131.9	128.0	127.5	117.0	122.0	120.0	115.0	108.0	105.0
H779L50	128.9	124.0	124.0	117.0	121.0	118.0	115.0	108.0	-0.0
H779L60	126.5	120.0	120.0	116.0	120.5	117.5	114.5	109.0	103.0
H779L70	124.6	116.5	117.0	114.0	119.0	117.0	115.0	108.5	103.0
H779L80	122.1	114.0	114.0	112.0	116.0	115.0	113.0	106.0	100.0
H841L40	127.9	123.0	125.0	117.0	115.0	111.0	106.0	98.0	-0.0
H841L50	125.6	120.0	122.5	113.0	117.0	111.0	107.0	99.0	96.0
H841L60	121.5	115.0	117.0	111.0	115.0	110.0	107.0	99.0	-0.0
H841L70	119.0	111.0	113.0	108.0	114.0	110.5	106.0	98.0	-0.0
H841L80	114.6	107.0	108.0	105.0	109.5	105.5	102.0	94.0	88.0
H842L40	131.5	126.0	128.0	122.0	121.5	118.0	113.0	106.0	106.0
H842L50	129.0	123.0	126.0	118.0	122.0	117.0	113.0	105.0	-0.0
H842L60	126.1	118.0	131.0	116.0	120.0	116.0	112.0	105.0	98.0
H842L70	122.9	114.0	116.0	112.5	118.0	115.0	112.0	105.0	99.0
H842L80	118.8	109.0	111.0	110.0	114.0	111.0	108.0	101.0	-0.0
H843L40	133.9	127.5	130.0	124.0	126.0	122.0	118.0	112.0	110.0
H843L50	132.9	126.0	129.0	122.0	126.0	121.0	118.0	111.0	107.0
H843L60	129.5	121.5	124.0	119.0	124.0	120.0	117.0	111.0	-0.0
H843L70	126.7	116.0	119.0	116.0	121.0	120.0	118.0	111.0	105.0
H843L80	122.5	111.0	113.0	113.0	117.0	117.0	113.0	107.0	100.0
H844L40	135.6	129.0	132.0	126.0	126.5	124.0	120.0	114.0	111.0
H844L50	134.6	127.5	130.0	124.0	128.0	124.0	121.0	114.5	109.0
H844L60	131.1	123.0	125.0	121.0	125.5	122.0	119.5	114.0	108.0
H844L70	128.9	118.0	120.0	118.0	123.0	123.0	121.0	114.0	109.0
H844L80	125.6	113.0	114.0	116.0	120.0	121.0	116.0	110.0	103.5

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-12



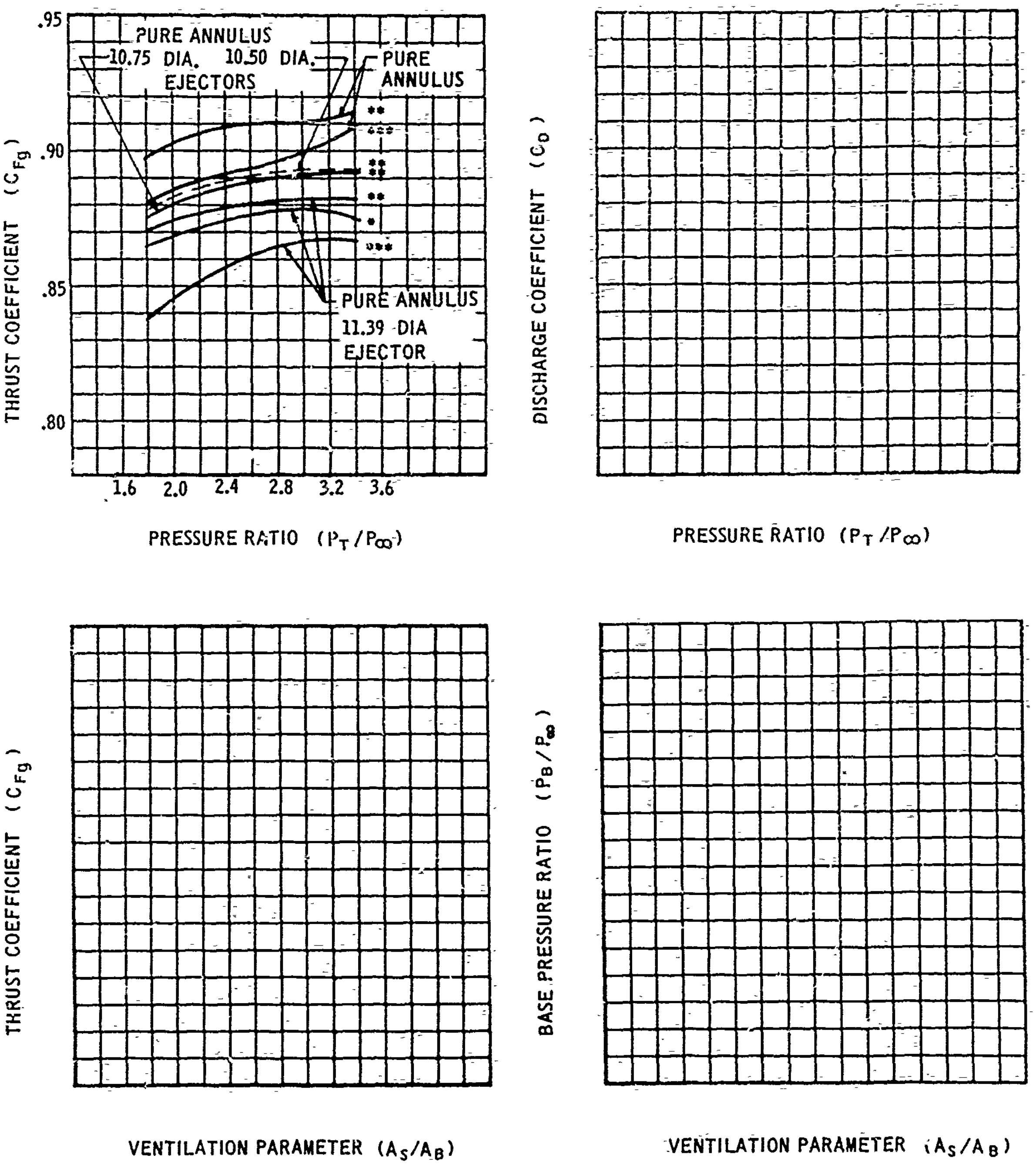
* = 8 CHUTES, BLEED OPEN, 100% PENETRATION

** = BLEED OPEN

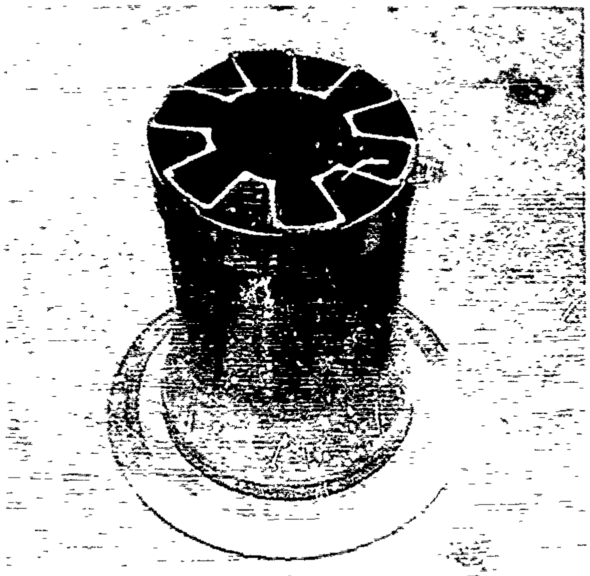
*** = BLEED CLOSED

$$C_{Fg} = \frac{(\text{THRUST} - \text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



HM-AP-15 NOZZLE
(6 SPOKES, AR 1.6)



Description

Number of Elements: 6 spokes

Area Ratio: 1.6

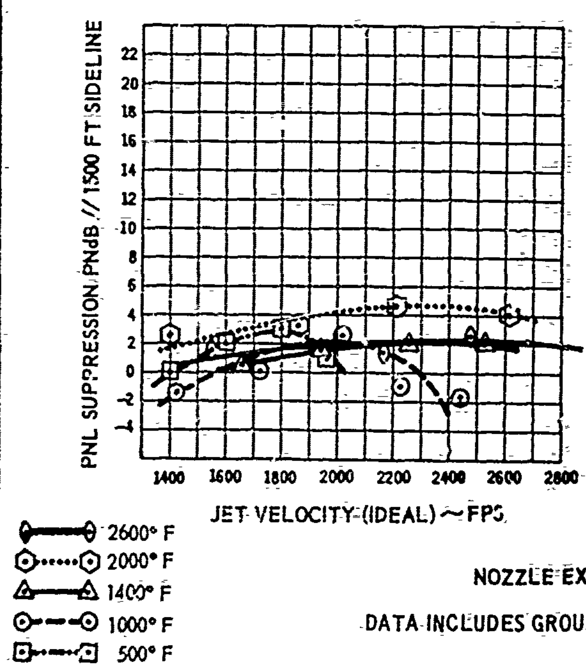
Spoke Penetration: 50%

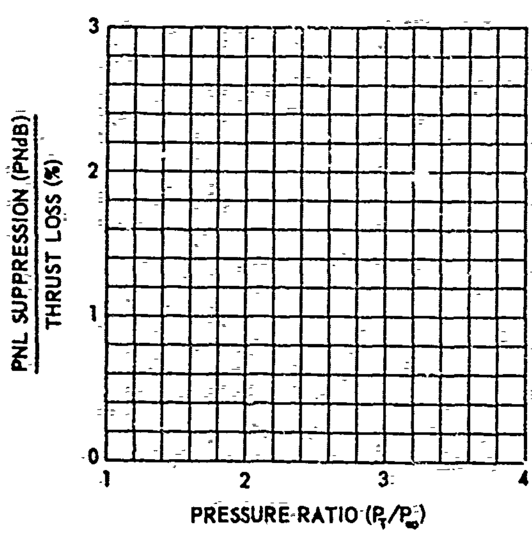
Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees

Ventilation Gutter Cant Angle:
~ 70 degrees

Material: 321 CRES

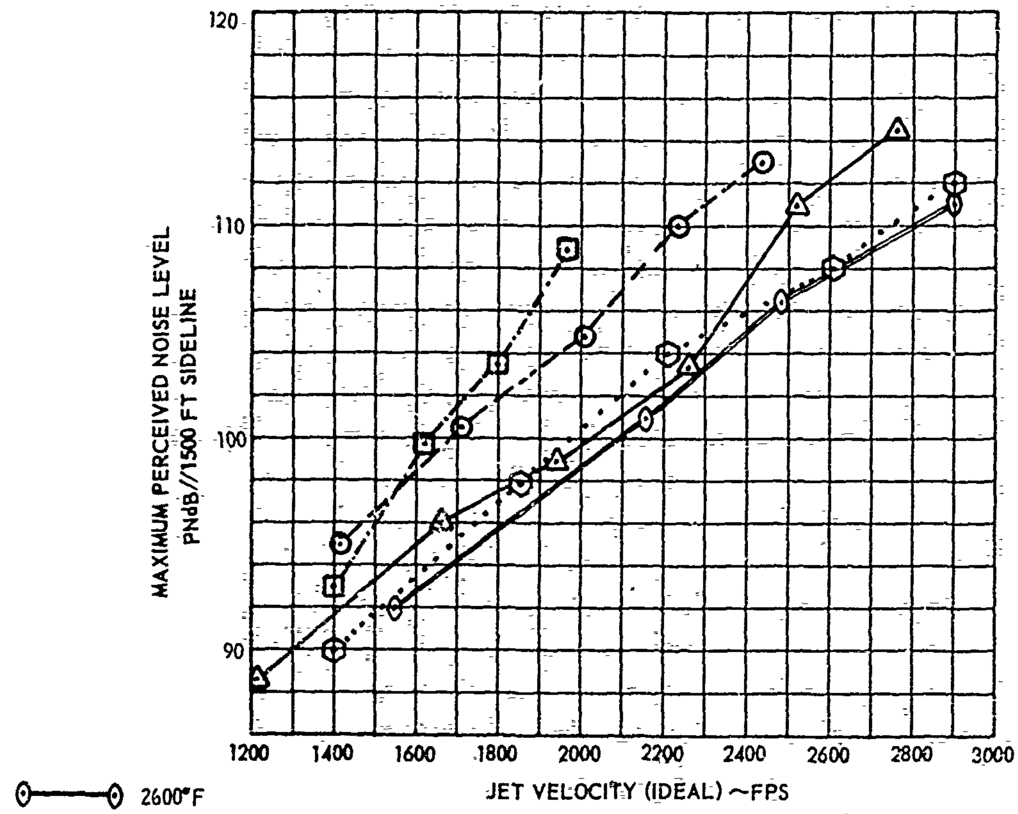




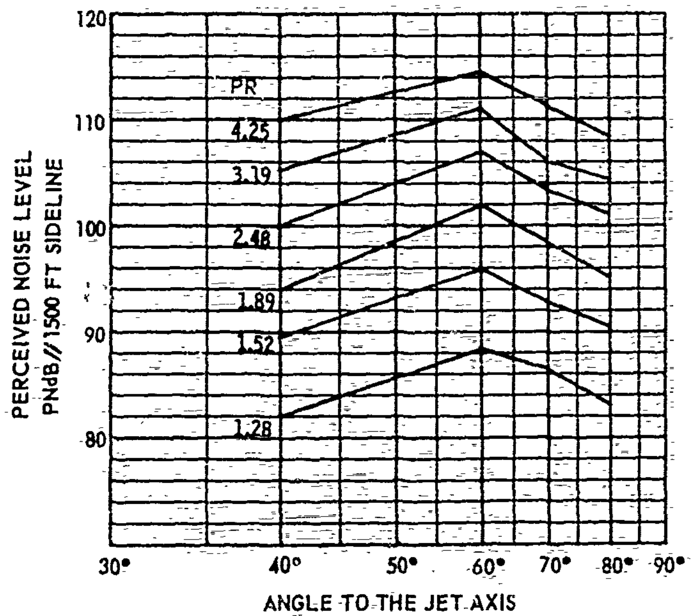
NOZZLE EXIT AREA (A_j): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-15 NOZZLE
(6 SPOKES)
AR 1.6
SCALE FACTOR: 8:1

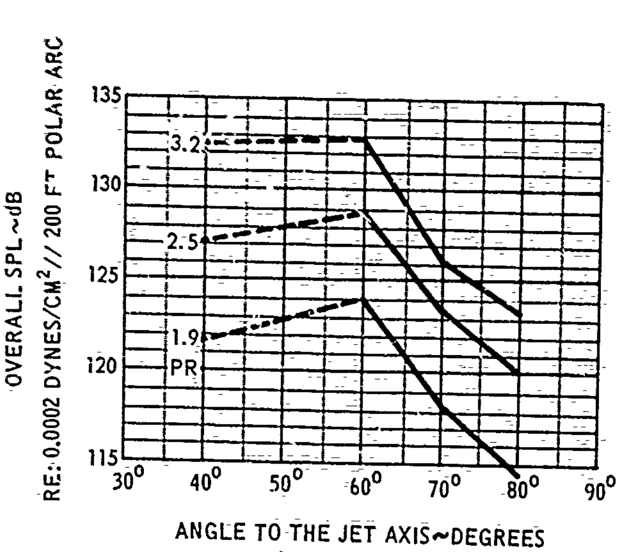


NOZZLE EXIT AREA (A_8): 5.9 FT^2

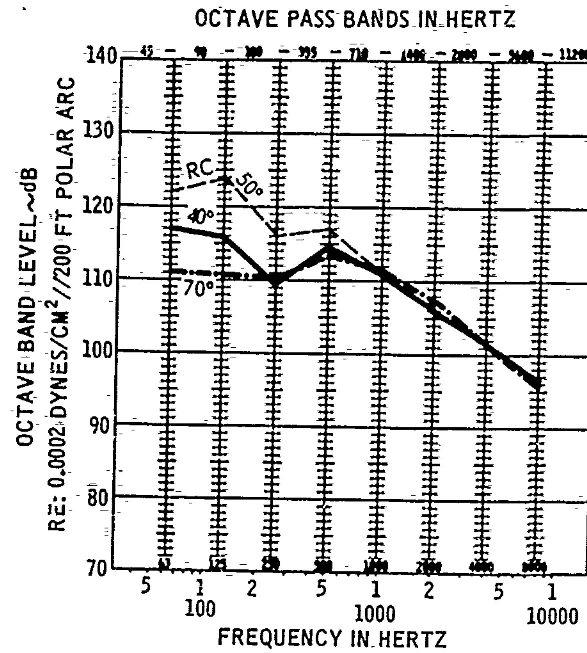


TOTAL TEMPERATURE (T_8): 1400° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

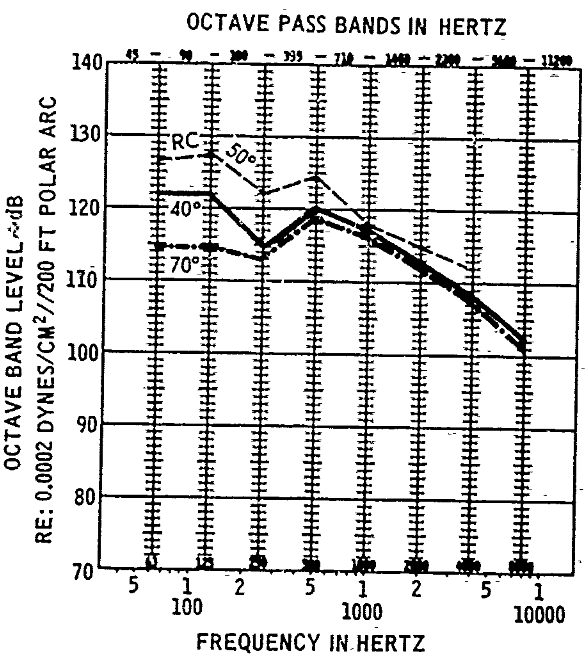


TOTAL TEMPERATURE (T_8) : 1400° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

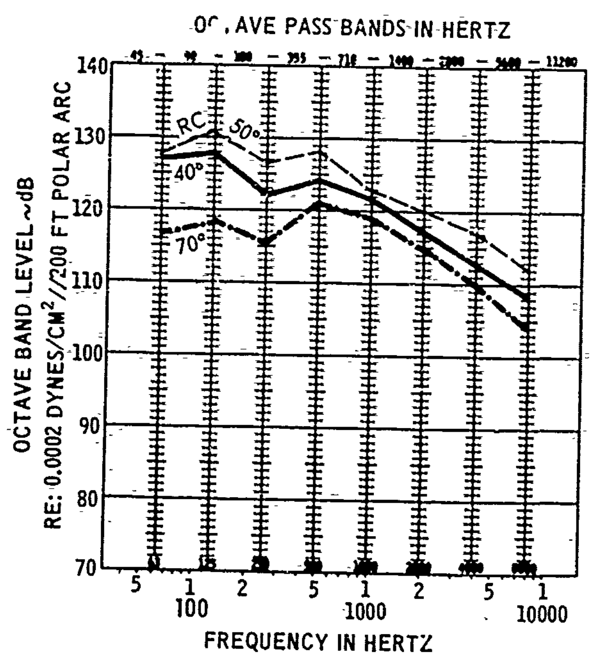


HM-AP-15 NOZZLE
(6 SPOKES)
AR 1.6
SCALE FACTOR: 8:1

PRESSURE RATIO: 1.9
TOTAL TEMPERATURE: 1400° F
JET VELOCITY (IDEAL): 1940 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 2.5
TOTAL TEMPERATURE: 1400° F
JET VELOCITY (IDEAL): 2260 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.2
TOTAL TEMPERATURE: 1400° F
JET VELOCITY (IDEAL): 2520 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-15

(6 Spokes, AR 1.6)

Remarks

The HM-AP-15 nozzle was tested at T_T equal to ambient, 500°F, 800°F, 1000°F, 1400°F, 1700°F, 2000°F, 2300°F, 2600°F, and 2900°F. Seven pressure ratios, ranging from 1.117 to 4.25 were tested at each temperature. Each condition was run at least twice and some conditions three or four times to check data consistency. It was noted that data repeatability was not very good, especially at the lower temperatures. The total temperature was based on a single point measurement in a region of the burner duct where an irregular and poorly shaped temperature profile was known to exist.

Maximum noise suppression attained by the HM-AP-15 nozzle was 4 to 5 PNdB. Suppression is likely to improve if spoke penetration had been deeper. Noise suppression trends were of interest. Maximum noise suppression tended to occur at a jet velocity of about 2200 fps. Negative suppression values occurred at a jet velocity below 1300 fps on the average. A deterioration in PNL suppression was noted at jet velocities above 2200 fps. These PNL suppression characteristics have been noted to occur with other multi-element nozzles tested over a wide range of gas conditions. The HM-AP-15 jet noise output was more sensitive to pressure ratio variations than temperature. See Reference D6.

HM-AP-15

(6 Spokes, AR 1.6)

Test Facility: Annex D (Cell #1)
Nozzle and Microphone heights are 20 inches.

Date:

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H 185	1.117	500°F	610 fps	HM-AP-15
H 186	1.275	"	860	"
H 187	1.524	"	1170	"
H 188	1.892	"	1400	"
H 189	2.483	"	1610	"
H 190	3.190	"	1800	"
H 191	4.250	"	1960	"
H 213	1.117	1000°F	690	"
H 214	1.275	"	1070	"
H 215	1.524	"	1420	"
H 216	1.892	"	1720	"
H 217	2.483	"	2010	"
H 218	3.190	"	2230	"
H 219	4.250	"	2440	"
H 227	1.117	1400°F	780	"
H 228	1.275	"	1210	"
H 229	1.524	"	1660	"
H 230	1.890	"	1940	"
H 231	2.483	"	2260	"
H 232	3.190	"	2520	"
H 234	4.250	"	2760	"
H 255	1.117	2000°F	910	"
H 256	1.275	"	1400	"
H 257	1.524	"	1860	"
H 258	1.892	"	2210	"
H 259	2.483	"	2610	"
H 260	3.190	"	2900	"
H 261	4.250	"	3190	"
H 301	1.117	2600°F	1020	"
H 302	1.275	"	1550	"
H 303	1.524	"	2160	"
H 304	1.892	"	2480	"
H 305	2.483	"	2900	"
H 306	3.190	"	3250	"
H 307	4.250	"	3560	"

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H 377	1.117	500°F	610 fps	4.1 Inch Round Convergent Nozzle
H 378	1.275	"	860	"
H 379	1.524	"	1170	"
H 380	1.892	"	1400	"
H 381	2.483	"	1610	"
H 382	3.190	"	1800	"
H 383	4.250	"	1960	"
H 391	1.117	1000°F	690	"
H 392	1.275	"	1070	"
H 393	1.524	"	1420	"
H 394	1.892	"	1720	"
H 397	2.483	"	2010	"
H 395	3.190	"	2230	"
H 396	4.250	"	2440	"
H 398	1.117	1400°F	780	"
H 399	1.275	"	1210	"
H 400	1.524	"	1660	"
H 401	1.892	"	1940	"
H 402	2.483	"	2260	"
H 403	3.190	"	2520	"
H 404	4.250	"	2760	"
H 356	1.117	2000°F	910	"
H 357	1.275	"	1400	"
H 358	1.524	"	1860	"
H 359	1.892	"	2210	"
H 360	2.483	"	2610	"
H 361	3.190	"	2900	"
H 362	4.250	"	3190	"
H 440	1.117	2600°F	1020	"
H 441	1.275	"	1550	"
H 442	1.524	"	2160	"
H 443	1.892	"	2480	"
H 444	2.483	"	2900	"
H 445	3.190	"	3250	"
H 446	4.250	"	3560	"

Measured acoustic data is recorded in Reference D2.

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-15

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H185 140	94.5	92.6	88.2	80.5	81.4	76.5	70.2	65.0	63.9
H185 160	94.8	92.2	88.1	83.1	85.2	80.8	76.2	71.2	66.0
H185 L70	93.4	90.6	85.7	81.4	85.5	81.1	74.9	68.4	63.8
H185 L80	91.3	88.0	84.1	80.6	83.0	79.5	75.0	70.2	65.7
H186 L40	102.6	100.1	97.0	89.2	91.5	86.9	81.0	75.8	73.9
H186 L60	102.4	98.7	96.0	91.1	94.1	91.1	87.2	81.5	77.6
H186 L70	101.6	97.1	94.0	90.6	94.7	92.8	87.9	80.6	75.0
H186 L80	98.3	93.7	90.8	88.0	90.9	89.9	85.4	80.8	75.2
H187 L40	110.1	106.4	104.5	97.4	102.1	97.5	92.3	87.7	84.3
H187 L60	109.5	103.6	102.1	98.5	103.6	100.6	97.4	92.8	86.2
H187 L70	106.3	99.4	97.5	95.4	101.1	99.2	94.6	89.1	81.5
H187 L80	103.7	96.3	94.7	94.0	97.4	96.5	94.5	89.8	80.6
H188 L40	116.2	111.8	110.6	104.0	108.8	105.8	100.8	95.6	88.5
H188 L60	114.5	107.6	106.3	104.0	109.3	106.0	103.2	99.1	91.5
H188 L70	112.3	104.0	103.2	101.3	107.1	105.7	102.4	96.9	90.6
H188 L80	109.6	100.8	99.8	99.5	103.6	103.0	100.9	97.2	89.0
H189 L40	123.0	117.7	116.9	110.8	116.4	113.6	108.9	104.7	98.6
H189 L60	121.1	113.1	112.3	110.0	115.7	113.8	111.1	107.8	102.2
H189 L70	118.7	108.5	107.9	106.7	113.7	112.9	109.5	104.8	99.4
H189 L80	116.3	104.2	103.9	103.9	109.0	111.7	109.0	106.0	98.3
H190 L40	128.7	123.1	123.3	116.8	121.9	118.7	113.8	110.2	106.5
H190 L60	124.9	115.6	115.8	114.7	119.7	117.5	114.3	111.5	105.8
H190 L70	122.9	111.8	111.7	111.9	117.6	117.5	113.8	108.8	103.3
H190 L80	121.9	108.1	108.2	110.2	115.9	117.2	114.5	110.4	102.8
H191 L40	134.5	129.2	130.6	124.6	125.8	121.1	116.0	112.3	107.9
H191 L60	130.8	123.2	122.6	121.7	125.1	123.3	119.1	115.8	101.1
H191 L70	128.9	117.3	117.6	120.5	124.2	123.0	117.7	112.9	108.0
H181 L80	136.6	113.4	113.5	119.2	121.8	120.5	116.3	113.1	105.5
H312 L40	97.0	94.9	91.5	83.8	82.3	78.4	71.3	69.7	73.0
H213 L60	99.8	96.9	94.1	88.2	90.3	85.0	79.3	71.9	74.8
H213 L70	94.3	91.5	87.5	82.2	85.9	81.4	75.6	68.9	63.8
H213 L80	92.8	89.7	85.5	91.4	84.6	81.0	75.5	70.9	65.2
H214 L40	108.1	105.2	103.4	94.5	96.8	91.0	84.2	81.2	83.2
H214 L60	110.1	106.1	104.1	99.4	102.6	97.5	92.1	84.5	85.4
H214 L70	104.7	100.2	97.1	93.0	99.3	94.2	88.2	82.0	75.4
H214 L80	101.9	97.7	94.2	91.8	94.7	92.5	87.9	83.4	76.1
H215 L40	115.1	111.3	110.4	102.4	106.3	100.9	94.8	89.2	84.6
H215 L60	117.3	112.0	111.7	106.6	110.8	106.1	102.5	96.4	90.3
H215 L70	111.2	105.6	104.2	100.1	105.1	102.4	98.0	91.9	85.9
H215 L80	108.7	102.9	101.2	97.5	102.3	100.6	96.9	92.9	86.2
H216 L40	120.9	116.5	116.0	109.1	113.0	109.1	103.8	99.5	95.4
H216 L60	122.7	116.4	116.7	112.8	116.5	112.9	109.4	104.4	100.1
H216 L70	116.3	109.0	108.5	104.9	111.3	108.6	104.0	99.0	93.0
H216 L80	113.0	105.6	104.5	102.3	107.0	105.6	102.9	99.5	91.7
H217 L40	126.1	121.3	120.8	114.0	118.7	115.4	111.0	106.5	100.7
H217 L60	127.1	120.2	121.2	116.9	121.1	117.6	114.6	110.2	105.4
H217 L70	121.2	112.6	113.0	110.2	116.5	113.8	110.1	105.4	100.4
H217 L80	117.4	108.2	108.0	105.7	111.5	111.0	108.4	105.4	98.1
H218 L40	131.9	126.7	127.4	120.5	123.6	121.5	115.1	111.7	107.7
H218 L60	131.7	124.6	125.0	121.8	126.2	122.6	118.6	114.0	110.9
H218 L70	124.8	115.4	116.2	113.9	120.3	118.0	113.2	108.6	103.5
H218 L80	122.2	111.6	112.3	111.3	116.3	116.5	113.4	109.7	102.8
H219 L40	136.8	131.7	133.2	126.8	126.8	122.4	116.7	112.7	108.3
H219 L60	135.6	129.1	130.5	126.1	128.5	125.5	121.8	117.5	113.9
H219 L60	135.6	129.1	130.5	126.1	128.5	125.5	121.8	117.5	113.9
H219 L70	129.2	120.2	121.3	119.0	124.2	122.2	117.4	112.6	108.2
H219 L80	126.6	115.0	116.3	117.1	122.1	120.5	116.0	112.4	105.6

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM²//25 FT

HM-AP-15

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H227 L40	99.7	97.5	94.4	86.6	85.9	81.6	74.6	71.1	74.2
H227 L60	101.3	97.8	95.5	90.7	93.2	87.5	82.1	74.4	75.5
H227 L70	97.7	94.2	90.4	86.5	90.6	86.7	80.1	74.0	71.7
H227 L80	94.6	91.3	87.1	83.8	86.4	81.4	79.2	73.9	65.8
H228 L40	110.4	107.4	105.7	97.8	99.3	94.4	87.7	83.1	83.7
H228 L60	111.6	106.9	106.1	100.9	104.4	100.9	94.7	86.9	86.0
H228 L70	107.7	102.6	100.9	96.3	101.5	98.6	93.1	86.2	82.2
H228 L80	103.3	98.8	95.9	92.5	96.0	94.1	90.8	85.4	7[illegible].4
H229 L40	117.3	113.3	112.8	105.6	107.6	104.0	98.5	92.5	85.9
H229 L60	118.7	112.9	113.3	108.2	112.4	107.3	104.1	97.8	89.6
H229 L70	113.2	107.3	106.3	102.3	107.3	104.8	100.5	93.4	86.0
H229 L80	110.7	104.7	102.6	100.5	104.6	102.6	99.5	94.9	86.3
H230 L40	121.6	117.0	116.0	109.5	114.2	110.9	106.3	94.9	86.3
H230 L70	124.0	116.8	117.8	114.8	118.2	114.6	111.4	101.7	96.5
H230 L70	118.7	111.0	110.8	108.6	113.4	111.4	107.3	105.9	100.5
H230 L80	114.4	106.6	105.3	104.4	108.3	107.4	104.8	101.6	95.8
H231 L40	127.1	121.9	121.6	114.7	120.3	116.9	112.7	100.6	91.2
H231 L60	128.9	121.2	122.9	119.5	123.2	119.6	116.0	108.5	102.5
H231 L70	123.4	114.3	114.9	113.1	118.7	116.5	112.1	111.5	106.0
H231 L80	120.0	110.6	110.5	109.2	114.5	113.5	111.2	107.3	101.0
H232 L40	132.5	126.9	128.0	121.9	124.5	121.7	116.7	107.3	99.4
H232 L60	133.0	125.5	127.9	122.9	127.0	122.9	119.9	112.9	108.5
H232 L70	126.1	116.8	118.2	115.5	121.2	119.1	114.5	115.0	111.3
H232 L80	123.3	113.2	113.5	112.5	117.6	117.3	114.2	109.9	104.2
H234 L30	99.6	97.9	93.4	85.9	82.1	78.6	70.6	110.6	102.7
H234 L50	100.0	97.4	94.7	88.0	88.3	83.7	77.4	70.5	73.7
H234 L60	100.1	97.1	94.1	88.9	91.2	85.4	80.2	73.4	74.6
H234 L70	98.9	95.4	92.1	87.3	91.4	87.4	81.2	73.0	74.1
H234 L90	93.9	89.2	87.1	83.4	87.0	84.3	79.5	75.1	74.0
H255 L40	100.7	98.6	95.1	87.9	87.2	82.1	74.8	74.1	66.8
H255 L60	100.8	97.7	94.3	89.9	92.9	86.9	80.4	71.7	74.7
H255 L70	100.2	96.4	92.5	88.9	93.7	89.5	82.7	73.3	74.4
H255 L80	95.7	92.3	88.1	85.0	88.0	84.7	80.1	75.9	73.5
H256 L40	112.1	108.8	107.5	100.9	100.8	97.8	90.1	74.6	66.9
H256 L60	112.0	107.5	106.6	101.5	104.6	100.3	94.9	83.8	84.8
H256 L70	110.8	105.2	103.6	99.7	105.0	102.7	96.9	87.5	85.0
H256 L80	105.9	101.1	98.3	95.5	99.1	97.3	92.6	89.0	84.2
H257 L40	119.2	114.7	114.6	108.5	109.9	107.2	101.0	87.7	78.3
H257 L60	119.6	113.4	113.6	109.8	113.9	109.3	104.5	95.8	95.0
H257 L70	118.1	110.5	110.1	107.3	113.5	1[illegible]0.7	104.6	97.9	95.4
H257 L80	112.8	106.5	104.6	103.2	106.3	105.3	101.5	97.9	89.6
H258 L40	124.2	119.0	118.5	113.0	117.3	114.0	109.0	96.8	88.2
H258 L60	124.5	117.5	118.8	115.0	118.7	114.5	110.7	104.2	98.6
H258 L70	123.7	114.8	115.5	112.9	119.4	116.4	111.4	105.5	100.1
H258 L80	117.3	109.8	109.0	106.5	111.6	110.3	106.6	104.9	98.7
H259 L40	129.9	124.0	124.2	118.0	123.8	120.6	115.1	102.5	93.3
H259 L60	129.9	122.5	123.5	120.2	124.9	120.2	115.7	111.2	107.8
H259 L70	127.9	118.0	119.4	117.3	124.0	120.8	115.2	110.9	107.8
H259 L80	122.2	113.4	113.2	111.9	117.1	115.4	112.1	109.9	103.8
H260 L40	132.9	127.2	128.4	122.2	125.3	121.8	116.6	108.0	100.5
H260 L60	133.6	125.8	127.1	123.7	128.9	123.8	119.3	112.4	108.5
H260 L70	121.2	121.6	123.1	121.7	126.5	12[illegible].4	118.9	114.9	110.7
H260 L80	125.3	115.3	115.4	115.8	119.8	119.4	114.8	113.8	108.9

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM²// 25 FT

HM-AP-15

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H261L40	136.5	132.1	132.3	126.5	126.6	122.5	117.7	113.7	109.3
H261L60	136.4	129.5	131.3	126.8	130.2	126.0	122.0	118.1	113.8
H261L70	133.6	124.4	126.3	124.5	128.6	126.1	121.2	116.2	111.3
H261L80	129.2	118.6	119.6	119.7	123.7	123.4	118.7	114.9	109.2
H301L30	104.0	102.2	98.3	89.8	87.1	81.7	74.6	71.0	73.1
H301L50	103.7	101.3	98.6	90.8	91.1	85.4	79.3	74.7	74.3
H301L60	104.0	100.6	98.1	92.9	96.0	89.1	83.4	77.8	74.2
H301L70	102.9	99.5	95.8	91.7	95.6	90.8	85.3	77.8	73.9
H302L30	114.1	111.8	108.5	101.6	101.5	94.9	88.7	83.2	83.2
H302L50	114.6	111.1	110.2	102.2	104.4	99.2	93.6	87.5	84.8
H302L60	114.8	110.2	109.4	104.6	107.3	102.4	97.3	91.1	85.3
H302L70	113.1	108.3	106.2	102.1	107.1	103.2	98.4	90.9	85.3
H302L90	106.8	100.9	99.9	97.2	100.1	98.3	94.3	88.6	80.7
H303L30	120.4	117.6	114.2	108.4	111.1	105.5	100.4	94.9	93.5
H303L50	122.1	117.6	117.7	110.3	113.5	109.2	104.6	98.8	95.5
H303L60	122.9	116.7	117.1	113.3	117.1	111.8	107.2	101.8	96.1
H303L70	121.1	114.4	113.9	110.3	116.3	112.0	107.4	100.4	95.5
H303L90	112.9	106.1	105.5	103.8	106.2	105.4	101.8	96.7	89.1
H304L30	125.7	123.2	117.3	112.8	117.3	113.7	109.0	104.0	97.6
H304L50	127.0	121.4	122.2	115.4	120.2	115.8	111.8	106.6	101.3
H304L60	127.5	120.3	122.0	118.6	122.1	116.1	111.2	105.4	98.7
H304L70	126.2	117.6	118.3	116.2	122.1	117.7	113.4	107.5	102.2
H304L90	116.8	108.4	108.7	108.1	110.5	109.9	106.5	102.5	94.0
H305L30	130.9	128.0	123.9	119.1	122.5	110.0	113.1	109.0	105.3
H305L50	133.1	127.3	127.9	121.7	126.5	122.7	118.6	114.0	109.9
H305L60	133.2	125.5	127.4	124.2	127.2	122.9	119.0	114.9	110.0
H305L70	130.9	122.1	123.7	121.1	126.4	122.2	118.0	112.7	108.4
H305L90	121.7	112.3	113.1	112.5	115.7	114.9	112.6	108.1	101.4
H306L30	134.6	132.3	128.0	122.9	124.3	118.4	113.7	109.4	105.6
H306L50	136.5	130.5	131.6	126.2	129.3	126.0	121.9	117.1	112.5
H306L60	136.7	128.3	129.9	127.8	131.9	127.1	123.3	119.3	114.4
H306L70	132.4	122.6	124.6	123.6	127.8	124.5	119.9	114.7	110.2
H306L90	125.1	114.1	114.5	116.4	118.4	119.9	116.3	111.7	104.8
H307L30	138.2	136.3	131.5	126.0	125.4	120.1	115.5	111.2	106.6
H307L50	141.0	135.0	136.7	131.1	133.2	129.1	124.7	120.9	118.0
H307L60	140.9	133.0	134.8	132.4	135.6	130.4	126.7	123.2	119.4
H307L70	136.2	126.7	129.0	127.4	131.8	127.5	123.5	118.6	114.2
H307L90	129.4	117.2	118.2	120.9	124.6	123.2	119.5	115.3	109.5
H377L30	96.1	94.9	89.1	79.6	72.0	75.6	0.0	0.0	0.0
H377L40	97.2	95.5	91.3	82.2	79.8	78.9	0.0	0.0	0.0
H377L50	94.9	93.0	89.0	81.1	80.3	76.0	68.8	0.0	0.0
H377L60	95.0	92.8	89.2	81.6	82.2	77.8	71.6	67.2	0.0
H377L70	92.7	90.7	86.8	78.8	79.9	75.1	69.7	62.6	0.0
H377L80	90.9	88.9	84.5	77.7	78.3	74.6	68.6	63.5	0.0
H377L90	89.6	86.9	83.7	78.9	78.4	74.8	69.2	64.6	0.0
H378L30	105.1	103.7	98.8	89.1	85.9	82.3	76.5	0.0	0.0
H378L40	105.9	103.6	100.5	92.0	93.4	87.4	82.5	0.0	0.0
H378L50	103.2	100.6	97.6	90.6	92.1	86.2	82.3	78.2	0.0
H378L60	102.4	99.2	96.9	91.1	93.0	87.7	94.3	79.2	0.0
H378L70	99.2	95.9	93.6	87.6	90.2	84.6	82.1	75.0	0.0
H378L80	96.7	93.0	91.1	85.6	87.9	83.8	80.2	74.5	0.0
H378L90	95.3	90.8	89.8	85.9	87.0	83.4	80.4	73.8	0.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-15

RUN NO	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H379L30	114.2	112.3	109.1	98.6	95.6	91.0	85.9	-0.0	-0.0
H379L40	113.9	111.3	[illegible]	100.1	102.1	95.7	91.5	86.6	-0.0
H379L50	110.3	107.0	104.6	98.7	101.4	95.4	92.2	88.2	-0.0
H379L60	108.4	104.0	102.6	98.1	101.0	96.2	93.4	87.3	-0.0
H379L70	104.8	99.7	98.8	94.3	98.2	93.4	91.8	83.5	-0.0
H379L80	102.4	96.7	96.0	93.0	95.9	92.1	89.0	83.7	-0.0
H379L90	101.6	94.7	95.2	93.2	95.4	91.9	89.4	83.0	-0.0
H380L30	122.1	118.9	118.3	110.0	106.0	100.8	95.7	-0.0	-0.0
H380L40	121.6	117.8	117.8	108.8	110.7	104.3	100.4	96.0	-0.0
H380L50	118.3	114.0	113.4	107.1	110.3	104.8	101.9	97.0	-0.0
H380L60	114.9	109.3	108.7	105.0	108.9	104.2	101.4	95.9	-0.0
H380L70	110.5	103.9	103.8	100.7	104.9	100.9	99.0	92.2	-0.0
H380L80	109.1	101.4	101.8	101.0	103.3	100.6	97.4	92.3	-0.0
H380L90	106.6	98.6	99.9	98.8	100.4	97.8	95.7	89.3	-0.0
H381L30	129.0	124.2	125.0	119.9	119.4	113.4	109.6	107.1	-0.0
H381L40	128.6	123.1	124.6	118.9	120.4	[illegible]	110.8	105.2	-0.0
H381L50	125.6	119.8	120.5	115.9	118.5	113.7	111.5	107.1	-0.0
H381L60	122.2	114.3	114.6	114.0	116.6	113.4	111.2	105.7	-0.0
H381L70	[illegible]	108.4	109.1	110.4	112.4	110.7	108.7	102.2	-0.0
H381L80	116.3	104.9	105.4	108.5	110.6	110.5	106.3	101.9	92.7
H381L90	116.6	103.9	105.1	109.1	111.7	110.3	107.2	101.3	93.2
H382L30	132.8	127.9	128.4	125.2	121.7	117.8	113.9	111.1	-0.0
H382L40	134.2	127.8	129.6	125.7	127.3	121.4	118.0	113.8	-0.0
H382L50	129.6	123.1	123.4	123.0	122.4	118.0	115.5	112.5	-0.0
H328L60	127.8	118.2	119.3	120.7	121.6	120.5	117.7	113.0	107.0
H382L70	125.0	111.6	115.3	120.5	118.6	116.8	114.5	107.8	101.6
H382L80	123.5	108.7	111.1	116.6	119.6	116.0	112.6	108.9	[illegible]
H382L90	124.1	108.1	110.0	116.6	121.1	115.6	113.0	107.7	101.3
H383L30	135.8	131.9	131.7	[illegible]	122.5	119.0	115.4	112.3	-0.0
H383L40	138.2	131.3	134.1	128.9	131.0	125.6	122.2	117.9	113.8
H383L50	132.8	126.3	127.1	123.6	126.0	122.5	120.2	117.4	112.2
H383L60	131.2	121.6	123.0	122.1	125.6	124.3	120.8	116.9	113.4
H383L70	128.0	114.8	118.5	119.0	124.0	120.4	118.3	112.5	-0.0
H383L80	128.1	111.6	115.8	120.5	125.0	120.0	116.6	113.4	-0.0
B383L90	128.9	112.2	118.7	123.3	124.8	119.9	115.9	112.5	-0.0
H391L30	100.6	99.4	93.8	84.0	77.5	75.6	69.2	-0.0	-0.0
H391L40	99.9	98.1	94.5	84.4	82.3	77.6	71.6	-0.0	-0.0
H391L50	98.3	96.0	93.3	84.6	83.6	77.5	72.4	-0.0	-0.0
H391L60	97.0	94.3	92.1	84.7	85.1	78.3	73.7	68.7	-0.0
H391L70	94.4	91.6	89.5	82.0	82.7	76.1	71.6	64.6	-0.0
H391L80	93.3	89.5	87.3	80.7	80.7	75.4	70.7	65.8	-0.0
H391L90	81.3	87.7	86.2	81.8	81.4	76.4	71.6	66.4	-0.0
H392L30	113.6	112.2	107.3	97.4	92.4	88.1	82.4	-0.0	-0.0
H392L40	112.6	110.7	107.2	97.5	96.9	90.6	85.0	-0.0	-0.0
H392L50	110.0	107.8	104.5	97.1	97.5	90.8	86.2	-0.0	-0.0
H392L60	108.1	105.0	102.7	96.7	98.5	91.7	87.3	81.1	-0.0
H392L70	104.5	101.0	98.9	93.7	96.0	90.0	86.1	78.4	-0.0
H392L80	101.6	97.8	95.9	91.9	93.3	88.3	83.6	78.9	-0.0
H392L90	100.6	95.3	95.2	92.3	93.3	88.6	84.5	78.5	-0.0
H393L30	121.6	119.3	117.2	107.5	103.4	97.9	92.3	-0.0	-0.0
H393L40	122.2	119.2	118.3	107.6	108.7	102.1	96.6	-0.0	-0.0
H393L50	119.4	116.4	115.0	106.6	107.8	101.5	97.2	-0.0	-0.0
H393L60	116.3	112.5	111.0	105.4	107.8	102.1	97.7	92.0	-0.0
H393L70	111.6	107.0	105.8	101.4	104.4	99.4	96.3	88.8	-0.0
H393L80	108.2	103.4	101.9	99.3	101.0	96.8	92.3	88.3	-0.0
H393L90	107.4	100.9	101.6	99.5	100.6	97.1	93.5	88.1	-0.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM²//25 FT

HM–AP–15

RUN NO	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H394L30	127.5	122.8	124.5	117.7	114.3	108.6	102.8	98.5	-0.0
H394L40	128.4	123.9	125.1	116.6	118.0	110.9	105.9	100.1	-0.0
H394L50	125.3	121.1	121.4	1[illegible]3.1	115.7	108.1	105.4	100.8	-0.0
H394L60	122.7	118.2	117.9	111.9	114.9	109.3	105.8	100.5	-0.0
H394L70	116.8	111.0	111.4	106.5	110.6	105.1	102.7	94.6	-0.0
H394L80	112.8	106.9	106.4	103.4	106.8	102.7	99.6	94.2	-0.0
H394L90	111.9	104.5	105.7	103.6	105.8	102.2	99.4	93.5	-0.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

OCTAVE BAND LEVEL ~ dB RE: 0.0002 DYNES/CM^2 // 25 FT

HM–AP–15

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H397L30	131.5	126.7	127.5	123.0	120.2	116.0	112.3	109.4	-0.0
H397L40	133.3	127.1	129.2	124.3	125.9	119.7	115.8	111.6	-0.0
H397L50	130.2	124.9	126.0	120.0	122.0	116.2	113.3	110.1	-0.0
H397L60	126.6	120.7	121.9	116.8	119.2	115.1	112.6	107.5	-0.0
H397L70	121.3	113.6	114.9	111.6	115.7	111.7	110.6	103.1	-0.0
H397L80	118.2	109.3	109.8	109.1	112.7	111.1	108.1	103.2	-0.0
H397L90	118.0	107.6	109.5	108.9	112.9	111.3	108.1	102.4	-0.0
H395L30	133.8	129.3	129.5	126.0	121.4	117.7	113.9	111.0	-0.0
H395L40	136.1	129.8	132.2	127.2	128.4	122.5	118.9	114.9	-0.0
H395L50	133.5	127.3	128.9	124.0	126.4	120.7	118.1	114.9	-0.0
H395L60	129.7	123.1	124.4	120.3	122.8	119.1	117.1	112.3	106.3
H395L70	125.2	115.7	117.3	116.5	119.8	117.3	115.7	108.8	101.8
H395L80	123.1	111.4	112.4	115.1	118.1	116.6	113.0	108.8	101.1
H395L90	123.9	110.2	111.8	115.6	120.5	115.8	113.8	108.3	101.3
H396L30	136.8	133.0	132.8	127.8	122.5	119.3	115.5	112.1	-0.0
H396L40	138.8	132.8	135.5	129.5	128.7	124.0	120.5	116.5	112.3
H396L50	136.4	130.3	132.0	127.0	128.9	124.0	121.2	118.5	113.0
H396L60	133.4	126.8	127.9	123.7	126.9	123.2	120.6	116.6	-0.0
H396L70	129.0	119.2	121.4	119.8	124.2	120.6	118.9	112.8	108.1
H396L80	127.9	114.5	118.1	119.8	124.2	119.8	116.7	113.8	-0.0
H396L90	128.6	114.1	118.2	121.1	125.2	120.2	117.3	112.8	-0 0
H398L30	103.3	102.4	95.6	86.3	79.7	77.6	70.3	-0.0	-0.0
H398L40	102.5	100.6	97.4	86.5	84.6	79.5	72.8	-0.0	-0.0
H398L50	100.8	98.6	95.7	87.1	86.1	79.2	73.7	-0.0	-0.0
H398L60	100.7	97.9	95.9	88.6	88.3	81.8	76.6	-0.0	-0.0
H398L70	97.2	94.2	92.3	85.4	86.1	78.8	75.1	-0.0	-0.0
H398L80	94.5	91.5	89.3	83.1	84.0	78.4	72.8	68.0	-0.0
H398L90	93.4	89.2	88.8	83.8	84.1	78.5	73.9	68.2	-0.0
H399L30	114.9	113.4	108.9	98.5	94.1	88.4	82.4	-0.0	-0.0
H399L40	115.2	113.1	110.4	99.8	99.7	92.2	86.6	-0.0	-0.0
H399L50	112.7	110.4	107.4	99.4	100.3	92.8	88.1	-0.0	-0.0
H399L60	111.0	107.7	105.9	100.2	101.5	94.9	90.3	-0.0	-0.0
H399L70	106.4	102.6	100.9	95.9	98.4	91.8	88.3	80.4	-0.0
H399L80	103.6	99.5	97.9	93.8	95.7	90.5	85.7	80.8	-0.0
H399L90	102.4	96.8	96.9	94.0	95.3	90.4	86.4	80.1	-0.0
H400L30	122.5	119.6	118.6	110.0	104.7	99.0	92.9	-0.0	-0.0
H400L40	123.6	120.1	120.2	109.4	110.4	103.3	97.7	-0.0	-0.0
H400L50	120.8	117.5	116.6	108.2	109.9	102.8	98.3	-0.0	-0.0
H400L60	118.1	114.2	113.4	107.3	109.1	103.7	99.3	93.1	-0.0
H400L70	113.5	106.5	108.0	103.2	106.7	101.1	98.1	90.4	-0.0
H400L80	109.9	104.8	103.7	100.9	103.1	98.6	93.9	89.8	-0.0
H400L90	108.4	101.4	102.9	100.1	102.0	98.0	94.8	88.8	-0.0
H401L30	129.9	125.5	125.8	122.2	117.0	111.8	106.2	-0.0	-0.0
H401L40	129.4	124.1	126.4	119.1	119.1	112.2	107.1	101.4	-0.0
H401L50	127.0	122.1	123.8	115.6	117.0	110.6	106.6	101.8	-0.0
H401L60	124.7	119.2	120.6	114.3	116.8	111.0	107.0	101.5	-0.0
H401L70	118.7	112.6	113.5	108.8	112.6	107.2	104.5	97.3	-0.0
H401L80	114.7	108.0	107.9	105.9	109.0	105.2	100.8	95.9	-0.0
H401L90	113.4	105.3	107.1	105.4	107.5	104.0	101.2	94.8	-0.0
H402L30	132.6	127.4	128.7	124.7	121.3	117.7	113.7	110.8	-0.0
H402L40	133.9	127.7	129.9	125.3	125.9	120.2	116.0	112.1	-0.0
H402L50	131.8	125.9	127.6	122.1	124.3	117.9	114.9	111.9	-0.0
H402L60	128.4	121.8	124.1	118.6	121.5	116.4	113.5	108.5	-0.0
H402L70	122.9	114.9	117.1	113.4	117.5	112.9	111.4	104.2	-0.0
H402L80	119.4	110.5	111.4	110.4	114.0	112.0	109.0	104.0	-0.0
H402L90	118.9	108.8	110.9	110.1	113.6	111.8	108.7	102.8	-0.0
H403L30	134.7	131.3	129.3	126.2	122.8	118.7	115.1	111.9	-0.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-15

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H403L40	136.3	130.3	132.3	127.3	128.4	122.6	119.1	114.7	-0.0
H403L50	135.2	128.6	130.7	126.2	128.2	122.7	120.2	117.1	111.9
H403L60	132.7	126.0	127.7	123.3	126.1	121.3	118.7	114.5	-0.0
H403L70	127.0	118.1	120.0	117.8	121.6	118.4	116.7	110.2	103.3
H403L80	125.0	113.1	114.3	116.3	120.1	119.1	115.1	110.6	103.2
H403L90	124.3	111.3	113.1	115.7	120.4	116.8	114.9	109.4	102.6

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

OCTAVE BAND LEVEL ~ dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-15

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H404L30	136.3	134.1	29.8	126.2	122.1	118.7	115.3	111.5	0.0
H404L40	138.4	133.0	35.0	128.8	128.0	123.6	120.4	115.9	0.0
H404L50	137.9	131.6	133.6	128.9	130.4	125.1	122.6	119.6	114.2
H404L60	135.2	128.6	130.1	126.0	127.8	124.6	122.0	117.9	113.9
H404L70	130.5	121.2	123.3	121.5	125.1	122.2	120.1	114.5	109.7
L404L80	128.6	116.1	118.3	120.6	124.0	121.6	118.2	114.6	109.2
H404L90	129.1	114.8	117.2	121.1	125.7	120.9	118.3	113.8	108.7
H356L30	105.8	104.8	98.5	89.1	81.5	77.5	70.1	0.0	0.0
H356L40	105.9	104.2	100.5	89.8	88.0	80.3	0.0	.0	0.0
H356L50	104.1	101.7	99.2	91.2	90.2	81.3	75.9	0.0	0.0
H356L60	103.1	100.1	98.3	91.6	91.9	83.6	77.3	0.0	0.0
H356L70	100.2	96.7	95.7	89.0	90.3	82.7	77.5	70.7	0.0
H356L80	97.3	93.7	92.4	86.8	88.0	81.8	76.1	72.1	0.0
H356L90	97.5	92.7	93.1	88.2	88.7	83.0	77.7	73.6	0.0
H357L30	118.0	115.7	113.7	103.1	98.4	91.8	84.7	0.0	0.0
H357L40	118.2	115.0	114.0	103.3	103.5	94.6	88.0	0.0	0.0
H357L50	115.7	112.8	111.2	103.4	103.8	95.1	89.8	0.0	0.0
HH357L60	113.6	110.1	108.2	102.7	105.1	97.5	91.7	86.9	0.0
H357L70	109.6	105.2	104.0	99.2	102.7	96.0	91.3	83.4	0.0
H357L80	106.1	101.0	100.5	96.7	99.6	93.7	88.1	82.5	0.0
H357L90	105.1	99.0	99.9	96.9	98.2	93.9	88.9	82.6	0.0
H358L30	126.1	122.0	122.8	116.1	110.7	102.8	95.9	0.0	0.0
H358L40	126.6	122.3	123.5	114.1	114.6	106.0	99.7	95.0	0.0
H358L50	124.7	120.4	121.2	113.1	114.5	106.3	101.2	96.5	0.0
H358L60	122.3	117.9	117.7	111.6	114.1	107.4	102.0	97.2	0.0
H358L70	117.0	111.7	111.4	106.9	110.8	104.9	100.1	91.7	0.0
H358L80	112.8	106.9	106.6	103.6	106.9	102.2	97.0	92.3	0.0
H358L90	112.0	104.6	105.9	104.3	105.9	102.1	97.8	91.8	0.0
H359L30	130.9	126.0	125.9	123.5	120.3	114.2	109.3	106.6	0.0
H359L40	132.2	126.8	128.3	122.8	124.1	116.4	111.5	107.8	0.0
H359L50	131.2	126.0	127.4	121.0	122.7	115.3	111.5	107.8	0.0
H359L60	128.2	122.8	124.0	117.9	120.8	114.8	110.5	0.0	0.0
H359L70	122.9	117.1	117.3	112.7	117.0	111.8	107.7	101.0	0.0
H359L80	118.0	111.4	110.8	108.9	112.6	108.6	104.1	99.2	90.6
H359L90	115.9	107.8	109.5	107.1	110.1	106.7	103.5	97.4	89.8
H360L30	132.8	128.3	127.8	125.1	121.0	117.9	113.5	110.8	0.0
H360L40	135.1	128.7	130.9	126.8	127.2	122.0	117.9	113.8	0.0
H360L50	135.1	128.0	130.7	126.9	127.6	123.0	120.1	116.6	111.7
H360L60	133.1	126.1	128.4	124.2	126.7	121.5	117.6	113.7	0.0
H360L70	127.2	119.2	121.6	117.6	121.7	117.5	114.5	108.4	102.1
H360L80	122.4	113.4	114.2	113.1	117.4	114.7	111.6	107.3	100.2
H360L90	121.4	111.3	113.1	113.0	116.2	114.3	110.9	105.5	99.1
H361L30	135.1	131.8	129.8	126.1	123.2	118.3	115.8	112.7	108.9
H361L40	137.2	131.3	133.1	128.1	129.3	123.3	119.8	116.1	111.9
H361L50	137.5	130.0	132.8	128.5	131.2	125.0	123.1	119.7	114.6
H361L60	135.9	127.5	130.2	126.9	130.6	125.6	122.4	118.6	114.4
H36LL70	130.4	121.1	123.7	121.0	125.6	121.5	118.6	113.5	108.6
H361L80	126.8	115.0	116.6	117.2	122.1	120.6	117.0	112.9	106.0
H361L90	125.5	113.5	114.9	116.4	121.1	118.9	115.4	111.0	105.2
H362L30	137.9	135.4	132.0	128.2	124.7	120.9	117.5	114.2	110.1
H362L40	139.4	134.2	135.7	129.8	129.6	124.8	121.6	117.6	113.2
H362L50	140.5	134.0	136.0	131.6	133.1	127.7	125.2	122.3	119.1
H362L60	137.8	131.0	132.4	128.4	131.7	127.2	123.9	120.3	115.9
H362L70	133.1	124.1	126.2	124.1	128.1	124.3	121.0	115.8	111.3

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-15

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H362L80	129.9	118.4	119.8	121.3	125.3	123.2	119.2	115.5	110.0
H362L90	130.4	116.9	118.6	121.8	127.2	122.4	119.3	114.7	109.9
H440L30	108.1	107.4	99.5	89.3	84.1	78.9	71.6	0.0	0.0
H440L40	107.3	105.4	102.4	89.8	87.3	79.7	0.0	0.0	0.0
H440L50	105.8	103.9	100.6	89.7	88.8	80.2	74.2	0.0	0.0
H440L60	104.1	101.6	98.9	91.5	92.1	82.8	76.9	71.2	0.0
H440L70	101.3	98.1	96.1	90.9	91.7	84.3	78.7	70.9	0.0
H440L80	99.1	95.4	94.3	88.8	90.1	82.4	76.5	70.9	0.0
H440L90	97.9	92.9	93.6	89.8	89.0	82.2	77.2	71.3	0.0
H441L30	119.2	117.0	114.4	105.8	99.2	93.4	84.4	0.0	0.0
H441L40	119.7	115.8	116.9	104.6	103.2	94.7	86.9	0.0	0.0
H441L50	117.4	114.3	113.7	103.5	103.7	95.2	89.0	0.0	0.0
H441L60	114.7	111.2	110.1	103.4	105.0	97.1	91.0	0.0	0.0
H441L70	110.7	106.5	105.2	100.5	103.7	96.2	90.9	83.0	0.0
H441L80	107.9	102.7	102.3	98.9	101.8	94.2	89.8	83.0	0.0
H441L90	106.3	99.6	101.3	99.3	99.3	93.6	88.0	82.5	0.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

OCTAVE BAND LEVEL ~ dB RE: 0.0002 DYNES/CM^2// 25 FT

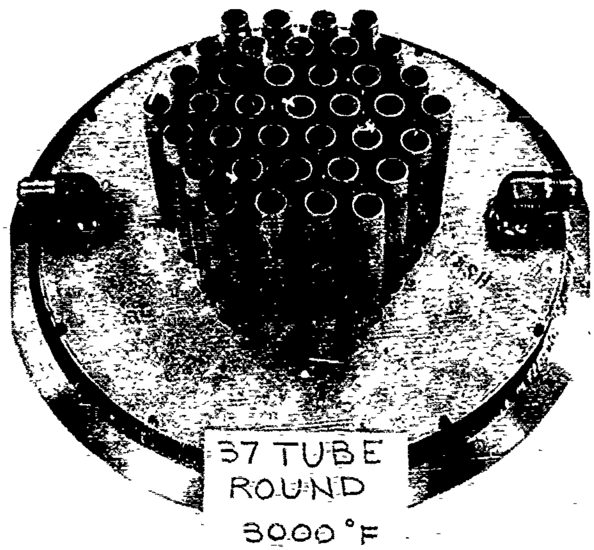
HM-AP-15

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H442L30	126.5	121.9	123.3	117.2	112.7	104.8	96.8	-0.0	-0.0
H442L40	127.0	121.8	124.6	115.3	114.2	106.2	99.4	-0.0	-0.0
H442L50	125.3	120.8	122.3	112.8	113.4	106.4	101.1	-0.0	-0.0
H442L60	122.5	117.9	118.4	111.5	114.3	107.1	101.4	95.7	-0.0
H442L70	118.1	113.1	112.3	108.2	111.9	105.5	101.5	93.5	-0.0
H442L80	114.3	108.3	108.5	105.4	108.5	102.4	98.5	92.2	-0.0
H442L90	112.4	104.8	106.9	105.2	106.1	101.1	97.3	91.3	-0.0
H443L30	129.8	125.8	124.9	121.1	120.2	113.5	107.5	103.9	-0.0
H443L40	131.3	124.8	128.0	121.8	123.4	115.9	111.2	105.4	-0.0
H443L50	130.9	125.2	127.2	120.1	123.2	115.7	111.6	106.5	-0.0
H443L60	128.6	122.6	124.2	118.3	122.1	115.5	111.6	106.5	-0.0
H443L70	123.6	117.4	117.9	114.0	117.7	112.5	109.6	102.5	-0.0
H443L80	119.4	112.3	112.5	110.4	114.5	109.2	105.1	99.8	-0.0
H443L90	116.7	107.8	110.1	109.9	110.9	107.4	103.3	97.7	-0.0
H444L30	132.3	129.4	126.7	123.0	120.0	116.7	110.9	106.7	-0.0
H444L40	133.8	127.6	130.4	124.6	125.1	119.0	114.1	109.2	-0.0
H444L50	134.7	128.2	130.3	124.7	128.6	121.3	118.1	113.3	-0.0
H444L60	133.8	126.2	128.5	124.4	128.6	122.1	117.9	114.2	108.5
H444L70	128.5	121.0	122.1	119.8	123.1	118.7	115.6	109.7	-0.0
H444L80	124.1	115.1	115.9	115.3	119.6	115.4	112.4	107.3	100.9
H444L90	121.8	110.8	112.9	114.9	116.4	114.7	110.8	105.0	95.7
H445L30	135.0	132.8	128.9	123.0	122.2	117.4	112.1	109.3	-0.0
H445L40	136.0	130.8	132.7	125.3	126.6	120.4	116.1	111.5	-0.0
H445L50	136.8	130.4	132.7	127.2	129.6	122.9	120.4	115.9	-0.0
H445L60	137.1	128.5	131.1	128.4	132.3	126.1	122.2	119.7	116.0
H445L70	131.6	122.9	125.2	123.0	126.5	122.1	119.3	113.1	109.0
H445L80	127.6	117.0	118.5	118.8	123.6	119.6	116.6	112.3	-0.0
H445L90	125.9	113.5	115.3	117.4	121.3	119.7	115.6	110.4	-0.0
H446L30	137.8	136.2	130.7	125.5	123.5	119.3	114.3	110.9	-0.0
H446L40	138.4	134.1	134.8	127.4	127.9	121.8	118.3	113.3	-0.0
H446L50	139.3	133.7	135.5	129.4	130.7	124.8	122.2	117.5	-0.0
H446L60	139.2	131.8	133.6	130.4	134.0	127.5	123.7	121.1	116.8
H446L70	134.4	126.7	127.8	125.7	129.1	124.5	121.8	116.3	-0.0
H446L80	130.9	120.8	121.5	122.5	126.9	122.8	119.1	114.7	110.3
H446L90	129.8	116.9	118.1	122.1	125.9	122.7	119.2	114.1	106.6

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-16 NOZZLE

(37 TUBE HEXAGONAL ARRAY AR 3.33)



Description

The HM-AP-16 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have round convergent terminations. The tubes were permanently installed in a 17-inch diameter water-cooled baseplate.

Number of Elements: 37 tubes with round convergent ends

Area Ratio: 3.33

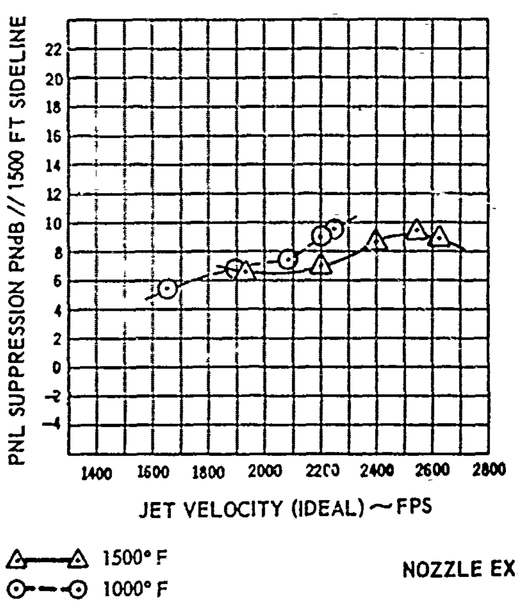
Flow Area: 13.2 square inches

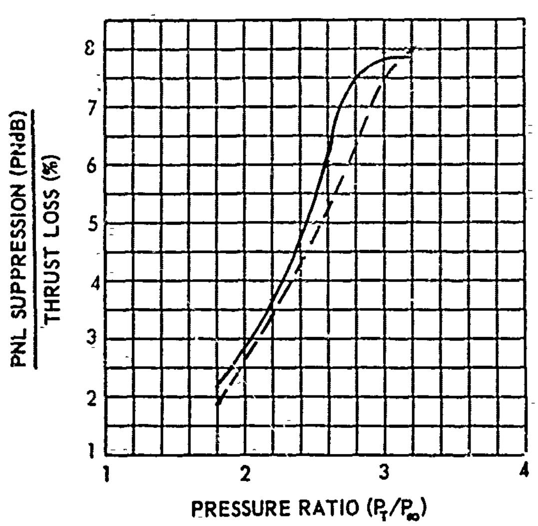
Exit Cant Angle: 0 degrees

Length of Tubes: 4.6 inches

Tube Exit Diameter: 0.674 inches

Material: 321 CRES

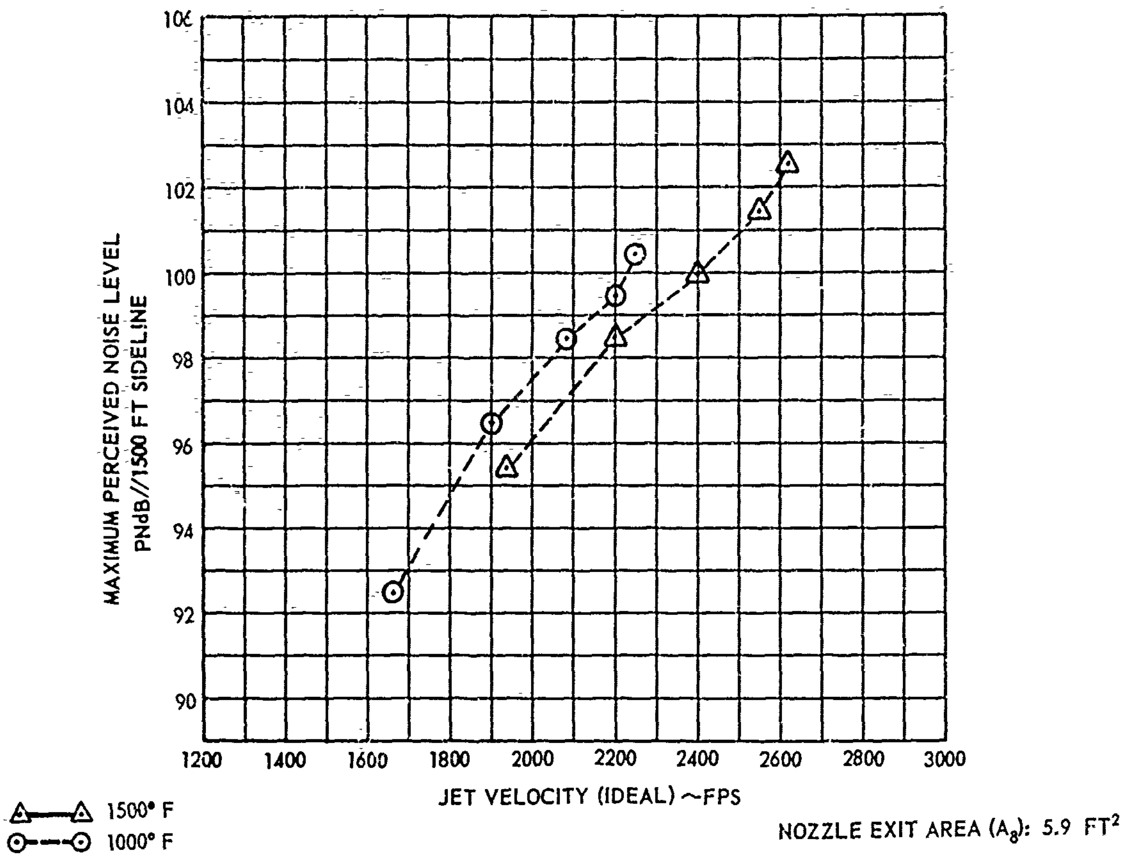


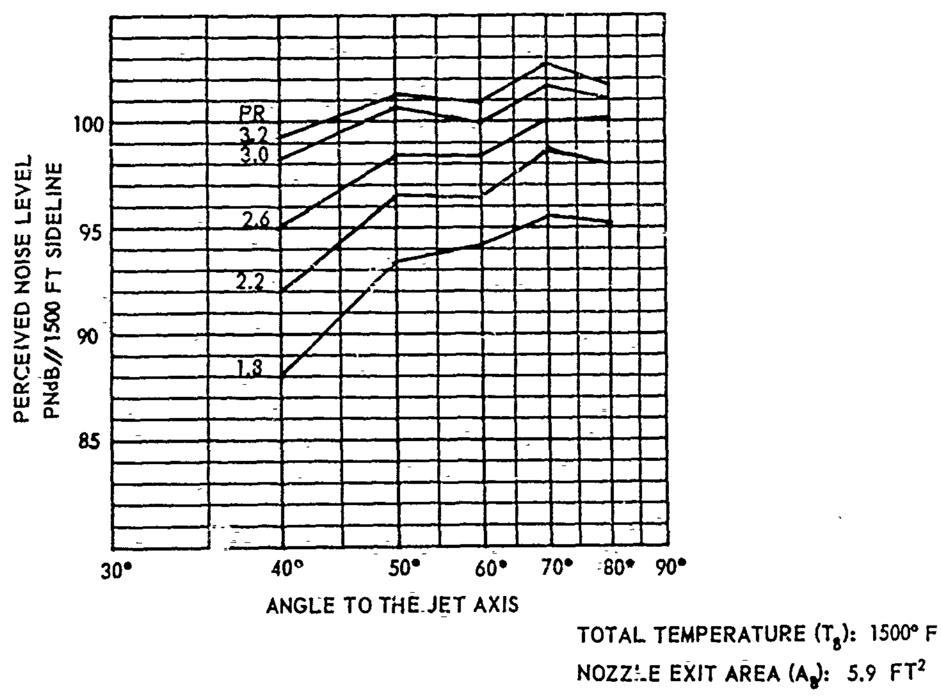


NOZZLE EXIT AREA (A_8): 5.9 FT^2

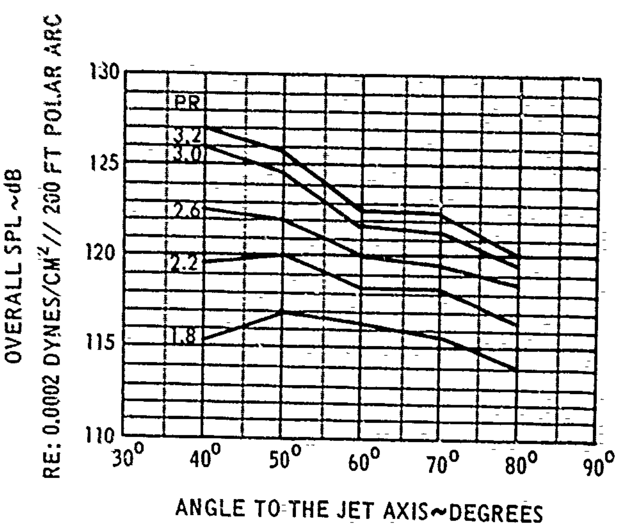
DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-16 NOZZLE
(37 TUBE HEXAGONAL ARRAY)
AR 3.33
SCALE FACTOR 8:1

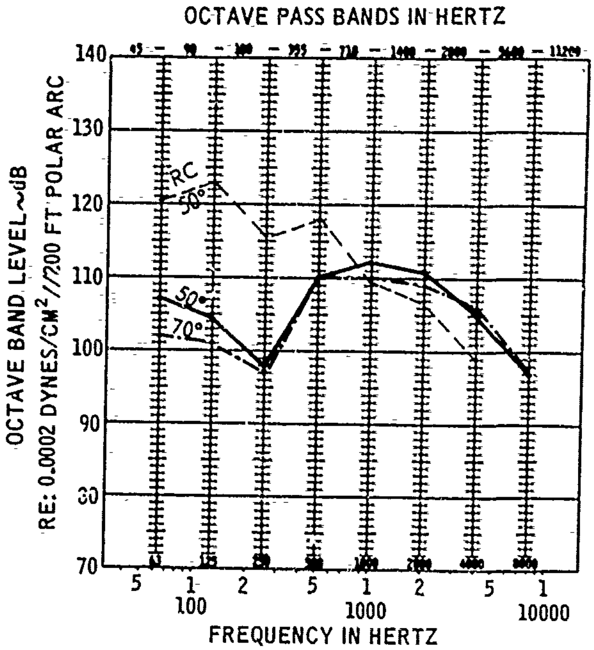




DATA INCLUDES GROUND REFLECTION INTERFERENCE

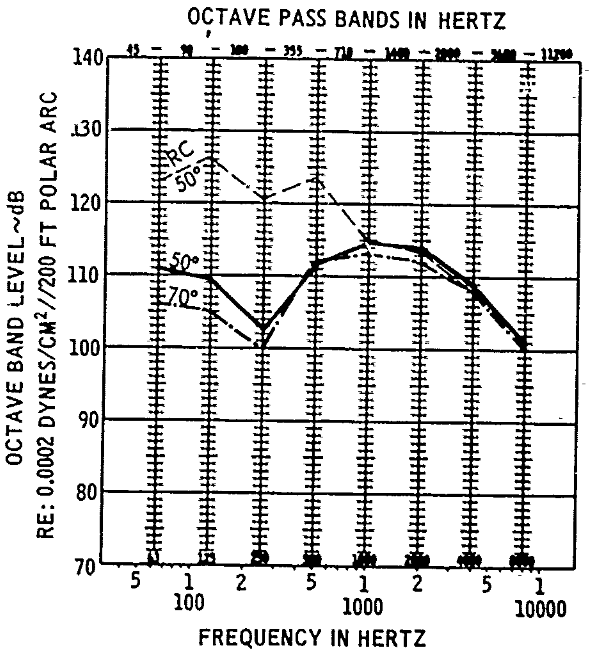


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

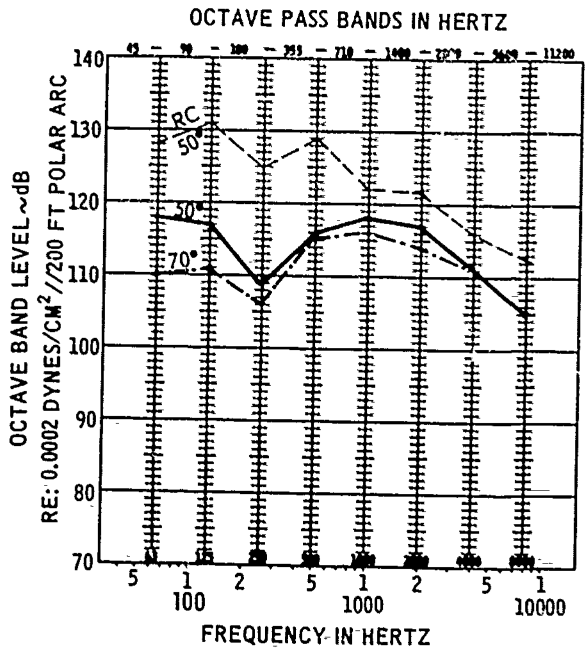


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1930 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

HM–AP–16 NOZZLE
(37 TUBE HEXAGONAL ARRAY)
AR 3.33
SCALE FACTOR: 8 : 1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2200 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2550 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-16

(37 Tube Hexagonal Array, AR 3.33)

Remarks

The noise characteristics of the HM-AP-16 nozzle are given in Reference D7. This nozzle is similar to the HM-AP-43 nozzle, except tube length is about 2.5 inches less.

HM-AP-16

Test Facility: Annex D (Cell #1)
Nozzle and microphone height is 20 inches.

Date: July 1967

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H 622	1.8	1000°F	1660 fps	HM-AP-16
H 623	2.2	"	1900	"
H 624	2.6	"	2070	"
H 625	3.0	"	2200	"
H 626	3.2	"	2250	"
H 627	1.8	1500°F	1930	"
H 628	2.2	"	2200	"
H 629	2.6	"	2400	"
H 630	3.0	"	2550	"
H 631	3.2	"	2620	"
H 637	1.8	1000°F	1660 fps	4.1 Inch Round Convergent Nozzle
H 638	2.2	"	1900	"
H 639	2.6	"	2070	"
H 640	3.0	"	2200	"
H 641	3.2	"	2250	"
H 642	1.8	1500°F	1930	"
H 643	2.2	"	2200	"
H 644	2.6	"	2400	"
H 645	3.0	"	2550	"
H 646	3.2	"	2620	"

NOZZLE TEST DATA

OCTAVE BAND LEVEL ~ dB RE: 0.0002 DYNES / CM^2 // 25 FT

HM-AP-16

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H622 L40	113.6	105.5	101.0	95.0	106.5	108.5	106.5	101.5	91.0
H622 L50	114.8	105.0	103.0	97.0	108.0	110.0	108.0	103.0	93.0
H622 L60	114.0	101.0	101.0	96.0	108.0	110.0	106.0	102.0	93.0
H622 L70	112.1	100.0	99.0	95.0	106.0	106.0	106.0	103.0	94.0
H622 L80	110.9	98.0	97.0	93.0	103.0	105.5	105.5	102.5	92.0
H623 L40	117.8	111.5	107.0	99.0	109.0	111.5	111.0	107.0	98.0
H623 L50	118.9	110.0	108.0	102.0	111.0	113.0	113.0	108.0	99.0
H623 L60	116.7	104.0	104.0	99.0	110.0	113.0	109.0	105.0	96.0
H623 L70	115.8	103.0	102.0	98.0	109.0	110.0	110.0	107.0	98.0
H623 L80	114.8	102.0	100.0	96.0	106.5	109.5	109.5	106.5	96.0
H624 L40	120.9	116.0	111.0	103.5	110.0	113.5	114.0	108.0	101.5
H624 L50	120.8	114.0	111.0	105.5	111.0	114.5	114.5	109.5	102.5
H624 L60	118.2	108.0	107.0	102.0	111.0	114.0	110.0	107.0	100.0
H624 L70	118.3	106.0	105.0	101.0	112.0	113.0	112.0	108.0	100.0
H624 L80	116.0	104.0	103.5	99.0	108.0	110.5	110.5	107.0	99.0
H625 L40	123.6	120.0	115.0	105.0	113.0	115.5	114.0	110.0	102.5
H625 L50	122.9	115.0	114.0	106.0	115.0	116.0	117.0	110.0	104.5
H625 L60	119.9	110.0	109.0	104.0	113.0	115.0	112.0	109.0	101.0
H625 L70	119.0	108.0	107.0	103.0	112.0	113.0	113.0	109.0	102.0
H625 L80	117.7	106.0	106.0	101.5	110.0	112.0	111.0	110.0	101.0
H626 L40	124.5	121.0	117.5	107.0	113.5	116.0	113.5	109.5	101.5
H626 L50	123.3	117.5	115.0	108.5	113.0	116.5	116.0	110.0	104.5
H626 L60	120.6	111.0	111.0	106.0	113.0	116.0	112.0	109.0	102.0
H626 L70	119.8	109.0	109.0	106.0	113.0	114.0	113.0	109.0	103.0
H626 L80	118.0	107.5	106.5	102.5	109.0	112.0	112.0	110.0	102.0
H627 L40	115.3	108.0	102.0	97.0	107.5	110.5	108.0	103.5	96.0
H627 L50	117.0	107.0	104.5	98.0	110.0	112.0	111.0	105.0	97.0
H627 L60	116.3	103.0	102.0	97.0	111.0	112.0	108.0	105.0	95.0
H627 L70	115.5	102.0	101.0	97.0	110.0	110.0	109.0	106.0	97.0
H627 L80	114.1	100.5	99.0	95.0	106.5	109.5	108.0	105.5	95.0
H628 L40	119.6	115.5	108.5	100.5	110.5	112.0	111.5	107.0	99.0
H628 L50	120.0	111.0	109.5	102.5	111.5	114.5	114.0	109.0	101.0
H628 L60	118.3	107.0	106.0	101.0	112.0	114.0	110.0	107.0	100.0
H628 L70	118.3	106.0	105.0	100.0	112.0	113.0	112.0	108.0	100.0
H628 L80	116.5	103.5	103.0	98.0	108.5	111.5	111.0	107.0	98.0
H629 L40	122.6	119.0	114.0	105.0	113.0	114.0	113.5	108.5	101.5
H629 L50	122.1	115.0	113.0	106.0	114.0	115.5	115.0	110.0	104.5
H629 L60	119.9	110.0	109.0	104.0	113.0	115.0	112.0	109.0	102.0
H629 L70	119.5	108.0	107.0	103.0	113.0	114.0	113.0	109.0	103.0
H629 L80	118.5	106.5	105.5	102.0	110.5	113.5	112.5	109.5	101.5
H630 L40	125.9	123.0	118.0	108.0	115.5	116.5	115.0	110.5	-0.0
H630 L50	124.6	118.0	117.0	109.0	116.0	118.0	117.0	111.0	105.0
H630 L60	121.7	112.0	112.0	106.0	115.0	117.0	113.0	110.0	103.0
H630 L70	121.4	110.0	111.0	106.0	115.0	116.0	114.0	111.0	105.0
H630 L80	119.4	108.5	107.5	104.0	111.5	113.5	113.5	110.5	102.5
H631 L40	127.0	124.5	120.0	111.5	116.0	115.5	114.0	110.0	-0.0
H631 L50	125.6	120.5	119.0	111.0	116.0	117.0	117.0	111.5	106.0
H631 L60	122.6	114.0	114.0	108.0	116.0	117.0	114.0	110.0	103.0
H631 L70	122.4	111.0	112.0	108.0	117.0	116.0	115.0	112.0	104.0
H631 L80	120.0	109.0	108.0	105.5	112.5	114.5	113.5	111.0	103.5
H637 L40	126.1	120.5	124.0	112.5	113.0	104.0	97.5	92.0	-0.0
H637 L50	123.7	119.5	120.0	111.5	113.5	106.5	102.5	95.0	-0.0
H637 L60	118.6	113.0	114.0	108.0	112.0	106.5	100.5	93.0	-0.0
H637 L70	115.2	109.0	109.0	105.0	110.0	104.0	101.0	94.0	-0.0
H637 L80	112.2	105.5	106.0	103.5	106.5	101.5	98.0	93.0	-0.0
H638 L40	129.3	124.0	126.0	118.5	120.5	111.0	106.0	103.0	-0.0
H638 L50	127.6	122.0	124.0	116.5	119.5	112.5	109.5	103.5	-0.0
H638 L60	122.3	116.0	117.5	111.5	116.0	111.5	107.0	101.5	-0.0
H638 L70	119.2	112.0	112.0	109.0	114.0	110.0	108.0	102.0	-0.0
H638 L80	115.9	107.5	108.5	107.5	110.5	107.5	104.5	98.5	98.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

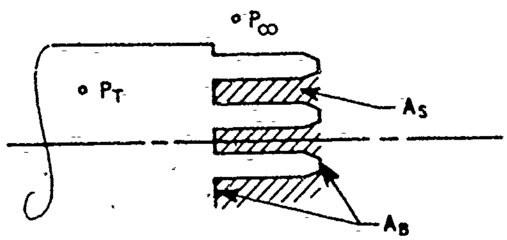
OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM²//25 FT

HM-AP-16

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H639L40	131.6	125.0	128.0	122.5	124.0	116.5	113.0	110.0	0.0
H639L50	130.4	124.0	127.0	120.5	122.0	116.0	114.5	109.5	0.0
H639L60	125.4	118.0	120.0	115.5	120.0	115.0	111.5	106.5	98.0
H639L70	123.0	114.0	115.0	113.0	118.0	115.0	113.0	107.0	100.0
H639L80	120.1	110.0	110.5	111.5	114.5	113.5	110.5	105.5	97.0
H640L40	133.6	127.0	130.0	124.0	126.0	119.5	115.0	113.0	107.5
H640L50	132.9	126.0	129.0	123.0	126.0	119.0	118.5	113.5	109.5
H640L60	127.8	120.5	122.0	117.0	122.0	118.5	115.5	110.0	101.5
H640L70	125.6	115.0	117.0	117.0	120.0	118.0	117.0	111.0	104.0
H640L80	123.0	111.5	112.5	114.5	118.0	116.5	113.5	109.5	[illegible]
H641L40	135.5	128.0	132.0	127.0	128.0	121.0	117.0	113.0	109.5
H641L50	134.2	127.0	130.0	124.0	128.0	121.5	119.0	114.5	110.5
H641L60	128.7	121.0	123.0	119.0	123.0	119.0	116.5	112.0	0.0
H641L70	126.6	116.0	118.0	117.0	122.0	119.0	117.0	112.0	105.0
H641L80	124.5	112.5	113.5	116.5	120.0	117.5	114.5	110.5	[illegible]
H642L40	127.0	121.0	124.0	117.0	118.0	107.0	103.0	97.0	0.0
H642L50	126.3	120.5	123.0	115.5	118.0	109.5	106.5	99.0	0.0
H642L60	121.5	115.5	117.0	111.0	115.0	109.0	103.5	97.0	0.0
H642L70	118.7	112.0	112.0	109.0	114.0	108.0	103.0	98.0	0.0
H642L80	114.7	106.5	108.0	106.5	109.5	105.5	101.5	95.0	0.0
H643L40	130.5	123.5	127.0	120.0	124.0	115.0	110.0	107.0	0.0
H643L50	130.0	123.0	126.0	120.5	123.5	115.0	113.5	108.0	0.0
H641L60	127.0	119.0	122.0	117.0	122.0	116.0	112.0	105.0	97.0
H643L70	122.2	114.0	115.0	113.0	118.0	112.0	109.0	103.0	97.0
H643L80	118.8	109.5	111.0	111.5	113.5	110.5	107.5	102.5	0.0
H644L40	132.2	125.0	128.0	122.0	126.5	118.0	114.5	110.0	0.0
H644L50	132.2	126.0	129.0	123.0	127.0	120.0	118.0	112.5	108.5
H644L60	129.2	120.0	124.0	120.0	124.5	118.0	114.5	110.0	0.0
H644L70	125.4	116.0	118.0	116.0	121.0	116.0	114.0	109.0	102.0
H644L80	121.8	111.5	112.5	113.5	116.5	114.5	112.5	107.5	99.0
ABORTED	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H645L40	133.8	127.0	130.0	124.0	127.0	119.0	115.0	112.5	107.5
H645L50	135.3	128.0	131.0	125.0	129.0	122.0	121.5	116.0	112.5
H645L60	130.2	122.0	125.0	120.0	125.0	120.0	116.5	112.5	0.0
H645L70	127.7	118.0	120.0	118.0	123.0	120.0	116.0	112.0	105.0
H645L80	124.6	113.5	114.5	115.5	119.5	118.5	114.5	111.5	104.0
H646L40	134.4	128.0	131.0	125.0	126.0	119.0	115.0	112.0	107.5
H646L50	135.9	128.0	132.0	126.0	129.0	123.0	123.0	117.5	112.5
H646L60	131.3	123.0	126.0	121.5	126.0	121.0	117.0	113.0	107.5
H646L70	128.1	119.0	121.0	119.0	123.0	119.0	117.0	113.0	108.0
H646L80	125.5	113.5	115.5	116.0	120.0	120.0	116.0	112.5	104.5

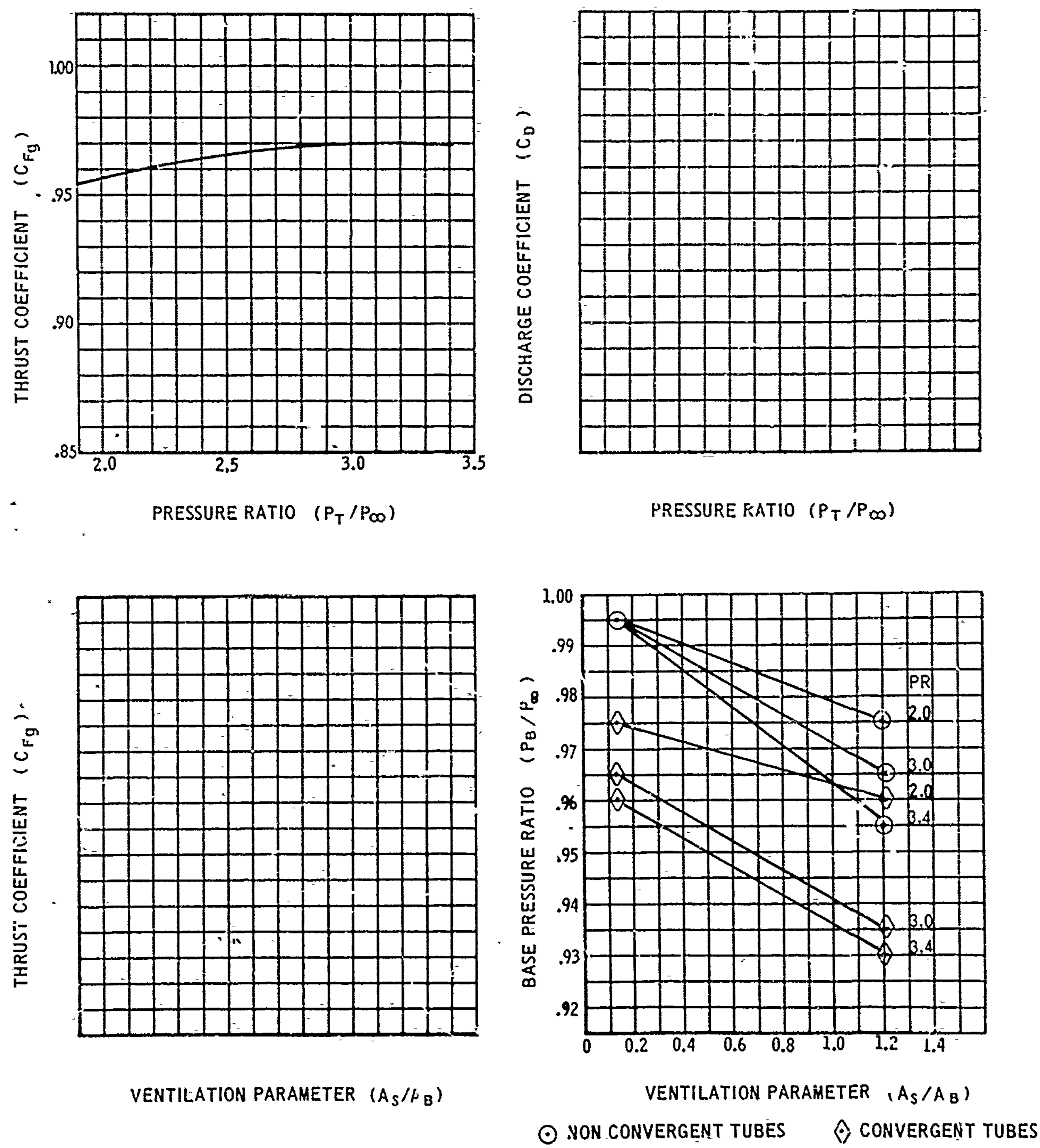
NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-16



$$C_{F_g} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



HM-AP-18 NOZZLE
(37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY, AR 4.65)

NO PICTURE AVAILABLE

Description:

The HM-AP-18 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have 12 spoke nozzle terminations. The tubes were inserted into a 17-inch diameter baseplate and were removeable.

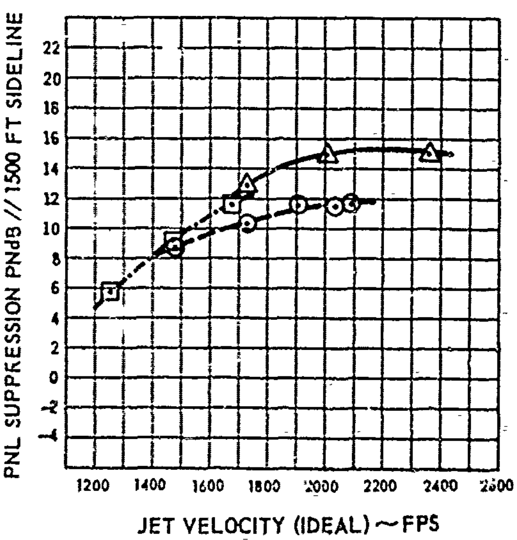
Number of Elements: 37 tubes with 12 spoke ends

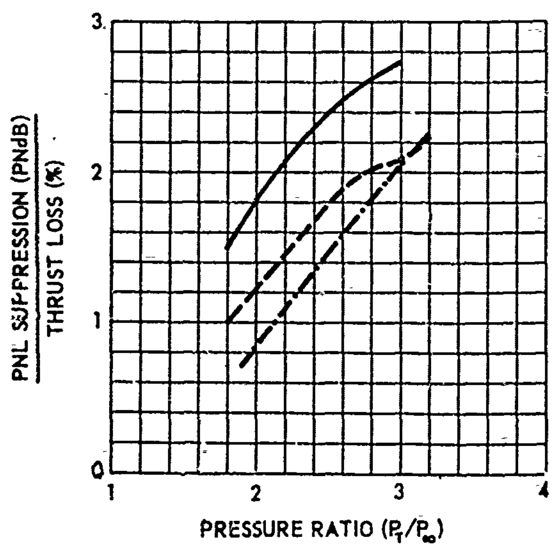
Area Ratio: 4.65

Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees

Length of Tubes:
7 inches
12 spoke terminations, AR = 1.86
Flow area = 0.357 square inches'
Exit cant angle = 0 degrees
Ventilation gutter angle = 77 degrees
Spoke penetration = 75%
Material: 321 CRES



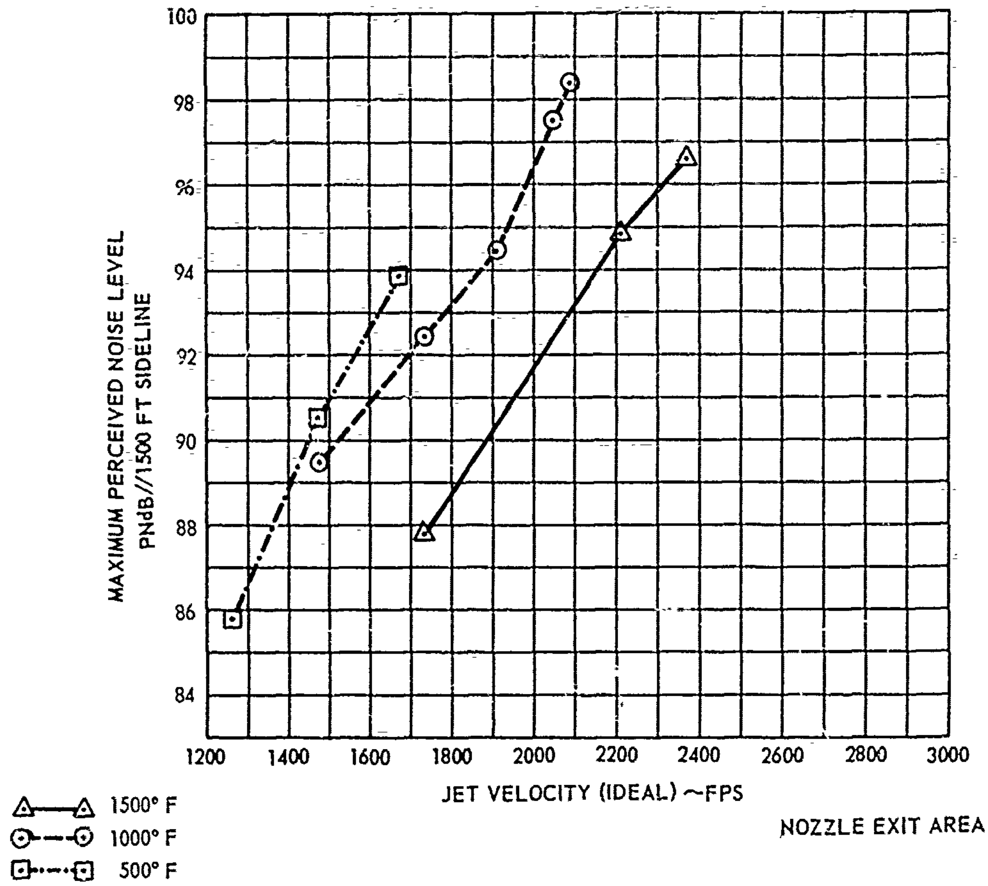


△——△ 1500° F
⊙- - -⊙ 1000° F
⊡ -·-⊡ 500° F

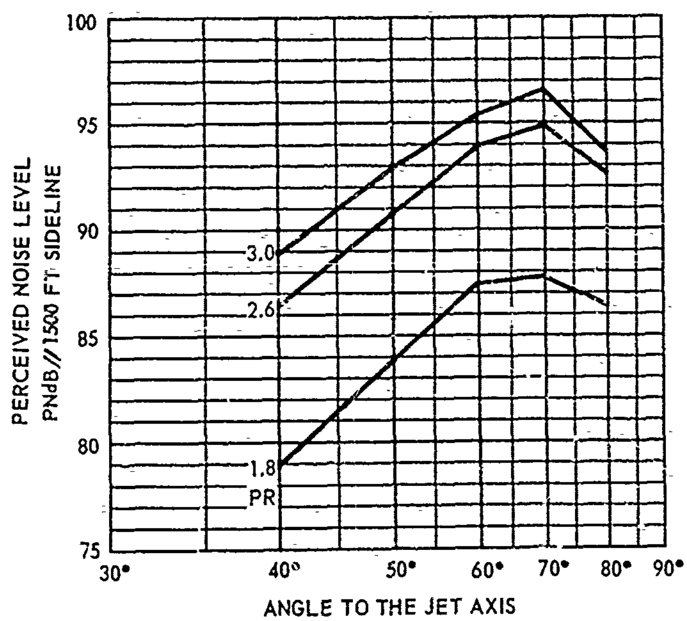
NOZZLE EXIT AREA (A_e): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-18 NOZZLE
(37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY)
AR 4.65
SCALE FACTOR: 8:1

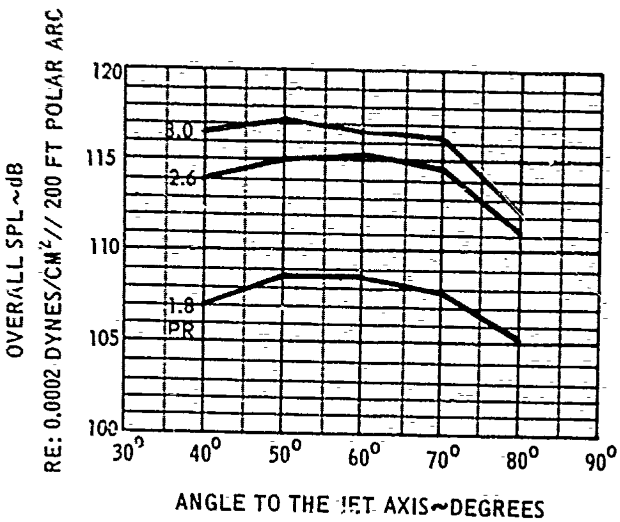


NOZZLE EXIT AREA (A_8): 5.9 FT^2



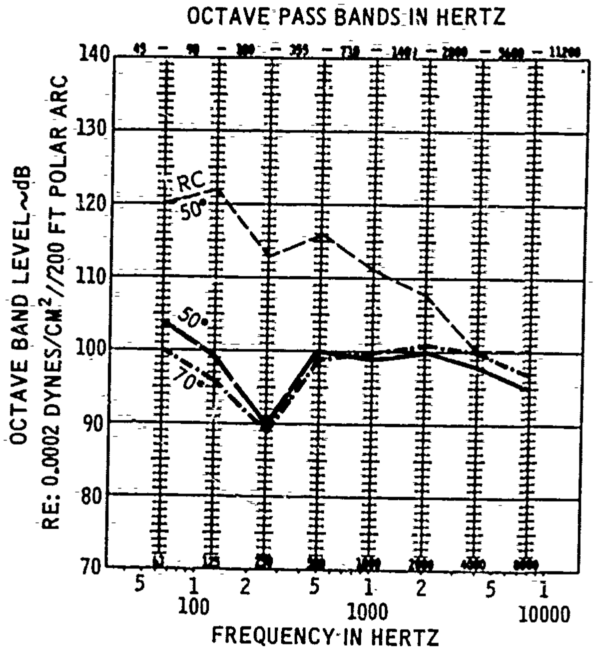
TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

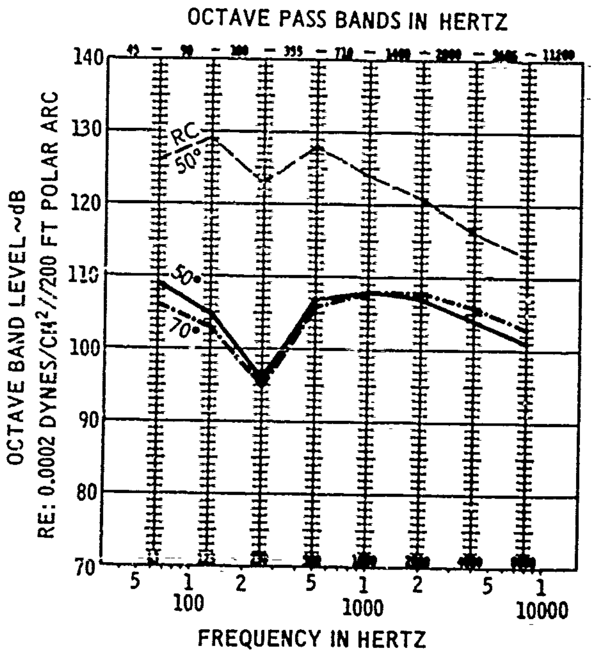


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

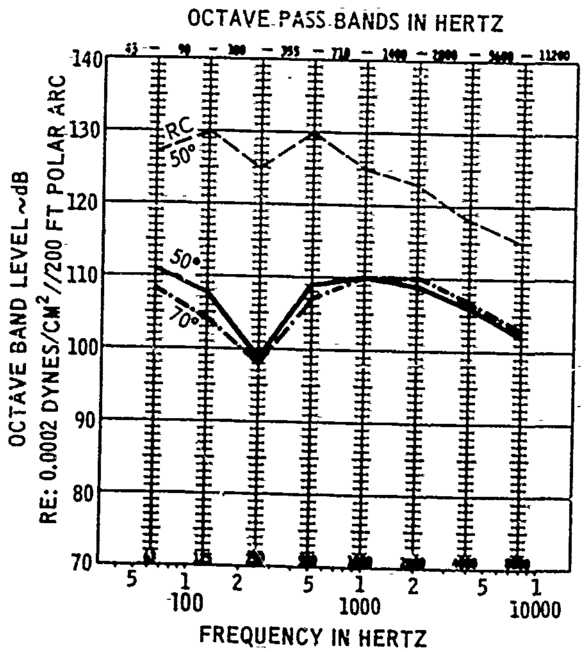
HM-AP-18 NOZZLE
(37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY)
AR 4.65
SCALE FACTOR: 8:1



PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1930 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2400 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2550 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-18

(37 Tube, 12 Spoke Ends, Hexagonal Array, AR 4.65)

Remarks

There were five different area ratios of the 37 tube hexagonal array (with 12 spoke terminations on each tube) tested:

HM-AP-18	AR 4.65
HM-AP-18a	AR 8.0
HM-AP-40	AR 3.33
HM-AP-41	AR 4.0
HM-AP-42	AR 5.2

The test results for the HM-AP-18 nozzle are discussed in References D7, D8 and D9. The nozzles with area ratios of 3.33 and 4.0 atteined highest PNL suppression values over the range of pressure ratios ($1.8 \geq 3.0$) and total temperatures ($500°F \geq 1500°F$) tested.

HM-AP-18

Test Facility: Annex D (Cell #1)
Nozzle and microphone height are 20 inches.

Date:

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H720	1.89	500°F	1400 fps	HM-AP-18
H721	2.48	"	1610	"
H722	3.19	"	1800	"
H729	1.8	1000°F	1660	"
H730	2.2	"	1900	"
H731	2.6	"	2070	"
H732	3.0	"	2200	"
H733	3.2	"	2250	"
H1128	1.8	1500°F	1930	"
H1129	2.6	"	2400	"
H1130	3.0	"	2550	"
H692	1.89	500°F	1400 fps	4.1 Inch Round Convergent Nozzle
H693	2.48	"	1610	"
H694	3.19	"	1800	"
H701	1.8	1000°F	1660	"
H702	2.2	"	1900	"
H703	2.6	"	2070	"
H704	3.0	"	2200	"
H705	3.2	"	2250	"
H1125	1.8	1500°F	1930	"
H1126	2.6	"	2400	"
H1127	3.0	"	2550	"

Measured acoustic data is recorded in Reference D2.

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM²/25 FT

HM-AP-18

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H720L40	105.0	101.0	96.0	88.0	96.0	96.0	96.0	93.0	84.0
H720L50	106.0	100.0	97.0	90.0	97.0	98.0	99.0	96.0	87.0
H720L60	106.1	98.0	94.0	87.0	96.0	99.0	101.0	98.0	89.0
H720L70	105.4	97.0	93.0	87.0	95.0	98.0	100.0	98.0	90.0
H720L80	103.2	95.0	91.0	85.0	94.0	96.0	98.0	95.0	86.0
H721L40	109.2	104.0	100.0	92.0	101.0	102.0	101.0	97.0	89.0
H721L50	110.1	103.0	101.0	94.0	102.0	103.0	103.0	100.0	92.0
H721L60	110.0	101.0	98.0	91.0	100.0	103.0	105.0	102.0	93.0
H721L70	109.9	100.0	97.0	91.0	99.0	103.0	105.0	103.0	94.0
H721L80	107.1	98.0	94.0	89.0	98.0	100.0	102.0	99.0	91.0
H722L40	114.8	110.0	106.0	96.0	106.0	108.0	106.0	101.0	93.0
H722L50	114.6	108.0	106.0	99.0	106.0	108.0	107.0	103.0	96.0
H722L60	113.8	106.0	103.0	97.0	104.0	107.0	108.0	105.0	97.0
H722L70	113.1	104.0	101.0	96.0	103.0	106.0	108.0	105.0	98.0
H722L80	110.7	102.0	99.0	94.0	102.0	104.0	105.0	102.0	94.0
H729L40	107.0	102.0	98.0	90.0	99.0	100.0	98.0	94.0	87.0
H729L50	107.7	101.0	100.0	92.0	100.0	100.0	100.0	96.0	89.0
H729L60	108.4	100.0	98.0	91.0	100.0	102.0	102.0	99.0	91.0
H729L70	108.6	98.0	97.0	90.0	99.0	102.0	104.0	100.0	92.0
H729L80	106.1	97.0	95.0	89.0	98.0	100.0	100.0	97.0	89.0
H730L40	110.3	105.0	101.0	94.0	102.0	104.0	101.0	97.0	89.0
H730L50	111.4	104.0	103.0	95.0	103.0	105.0	104.0	100.0	93.0
H730L60	111.2	103.0	100.0	94.0	103.0	105.0	105.0	101.0	94.0
H730L70	111.6	101.0	99.0	93.0	102.0	105.0	107.0	103.0	95.0
H730L80	108.8	99.0	97.0	92.0	100.0	103.0	103.0	100.0	92.0
H731L50	114.3	107.0	106.0	98.0	106.0	108.0	107.0	102.0	95.0
H731L60	113.8	106.0	103.0	96.0	106.0	108.0	107.0	103.0	96.0
H731L70	113.7	104.0	101.0	95.0	104.0	107.0	109.0	105.0	97.0
H731L80	111.0	102.0	100.0	94.0	103.0	105.0	105.0	101.0	94.0
H732L40	116.6	112.0	107.0	100.0	107.0	111.0	107.0	101.0	95.0
H732L50	116.8	110.0	108.0	101.0	108.0	111.0	109.0	104.0	96.0
H732L60	115.9	108.0	106.0	100.0	108.0	110.0	109.0	105.0	97.0
H732L70	116.4	106.0	104.0	99.0	107.0	110.0	112.0	107.0	99.0
H732L80	113.0	104.0	102.0	97.0	105.0	107.0	107.0	103.0	96.0
H733L40	118.0	114.0	109.0	101.0	108.0	111.0	109.0	103.0	96.0
H733L50	117.9	111.0	110.0	103.0	109.0	112.0	110.0	104.0	97.0
H733L60	116.9	109.0	107.0	101.0	109.0	111.0	110.0	106.0	98.0
H733L70	117.2	107.0	105.0	100.0	107.0	111.0	113.0	107.0	99.0
H733L80	114.0	105.0	103.0	98.0	106.0	108.0	108.0	104.0	96.0
H1128L40	106.9	103.0	97.0	89.0	99.0	97.0	97.0	95.0	92.0
H1128L50	108.5	104.0	99.0	90.0	100.0	99.0	100.0	98.0	95.0
H1128L60	108.6	101.0	97.0	91.0	100.0	101.0	103.0	99.0	94.0
H1128L70	107.8	100.0	96.0	89.0	99.0	100.0	101.0	100.0	97.0
H1128L80	105.2	97.0	94.0	88.0	96.0	97.0	99.0	98.0	93.0
H1129L40	114.0	109.0	104.0	96.0	106.0	107.0	105.0	102.0	98.0
H1129L50	115.0	109.0	105.0	96.0	107.0	108.0	107.0	104.0	101.0
H1129L60	115.3	107.0	103.0	97.0	108.0	109.0	109.0	105.0	100.0
H1129L70	114.6	106.0	103.0	95.0	106.0	108.0	108.0	106.0	103.0
H1129L80	111.3	103.0	99.0	93.0	102.0	104.0	105.0	104.0	99.0
H1130L40	116.5	111.0	107.0	98.0	108.0	110.0	108.0	104.0	100.0
H1130L50	117.1	111.0	108.0	99.0	109.0	110.0	109.0	106.0	102.0
H1130L60	116.6	109.0	106.0	99.0	109.0	110.0	110.0	106.0	100.0
H1130L70	116.2	108.0	104.0	98.0	107.0	110.0	110.0	107.0	103.0
H1130L80	112.2	104.0	101.0	95.0	103.0	105.0	106.0	104.0	99.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

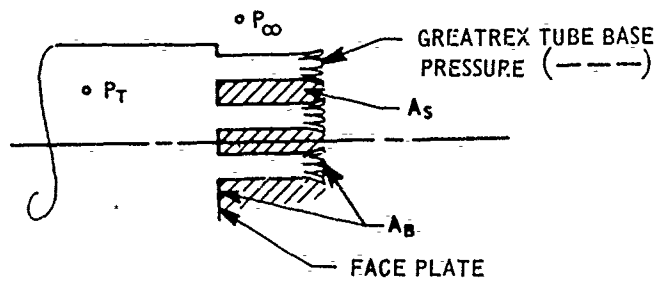
OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-18

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H692 L40	120.4	117.0	117.0	106.0	106.0	100.0	95.0	87.0	-0.0
H692 L50	116.2	112.0	112.0	104.0	107.0	102.0	99.0	90.0	89.0
H692 L60	112.1	107.0	106.0	101.0	106.0	101.0	98.0	91.0	-0.0
H692 L70	110.4	104.0	103.0	100.0	105.0	101.0	99.0	91.0	-0.0
H692 L80	107.6	101.0	101.0	98.0	102.0	98.0	95.0	87.0	82.0
H693 L40	127.2	121.0	124.0	120.0	115.0	110.0	104.0	97.0	-0.0
H693 L50	122.6	117.0	118.0	113.0	115.0	110.0	107.0	99.0	-0.0
H693 L60	118.6	111.0	111.0	110.0	113.0	110.0	108.0	100.0	-0.0
H693 L70	118.5	108.0	108.0	113.0	112.0	111.0	109.0	100.0	95.0
H693 L80	116.2	105.0	106.0	110.0	111.0	109.0	105.0	98.0	93.0
H694 L40	132.7	126.0	130.0	123.0	123.0	117.0	112.0	106.0	107.0
H694 L50	128.7	122.0	124.0	120.0	121.0	118.0	115.0	108.0	-0.0
H694 L60	125.0	115.0	116.0	116.0	119.0	119.0	115.0	109.0	105.0
H694 L70	124.7	112.0	114.0	117.0	120.0	118.0	115.0	108.0	105.0
H694 L80	123.6	109.0	111.0	115.0	121.0	115.0	112.0	106.0	101.0
H701 L40	126.2	121.0	124.0	112.0	113.0	106.0	99.0	91.0	99.0
H701 L50	122.7	118.0	119.0	110.0	114.0	107.0	103.0	95.0	-0.0
H701 L60	118.1	113.0	113.0	106.0	111.0	107.0	103.0	95.0	92.0
H701 L70	115.2	109.0	108.0	104.0	110.0	106.0	103.0	95.0	91.0
H701 L80	111.4	105.0	105.0	101.0	106.0	102.0	98.0	91.0	-0.0
H702 L40	130.0	124.0	127.0	119.0	121.0	114.0	108.0	101.0	-0.0
H702 L50	127.7	122.0	124.0	116.0	120.0	113.0	110.0	102.0	102.0
H702 L60	122.0	116.0	117.0	111.0	115.0	112.0	109.0	101.0	-0.0
H702 L70	119.3	112.0	112.0	109.0	114.0	112.0	111.0	102.0	-0.0
H702 L80	116.0	108.0	108.0	106.0	111.0	108.0	105.0	98.0	91.0
H703 L40	133.3	127.0	130.0	123.0	125.0	119.0	113.0	107.0	108.0
H703 L50	130.3	124.0	127.0	119.0	122.0	117.0	114.0	107.0	108.0
H703 L60	125.1	118.0	119.0	114.0	119.0	116.0	114.0	108.0	104.0
H703 L70	123.5	114.0	114.0	112.0	117.0	117.0	117.0	108.0	104.0
H703 L80	120.3	110.0	110.0	109.0	115.0	115.0	111.0	105.0	100.0
H704 L40	135.5	129.0	132.0	125.0	128.0	122.0	117.0	111.0	111.0
H704 L50	133.2	127.0	129.0	123.0	126.0	121.0	118.0	112.0	111.0
H704 L60	128.4	121.0	122.0	118.0	122.0	120.0	118.0	112.0	108.0
H704 L70	127.1	117.0	117.0	115.0	121.0	121.0	120.0	113.0	109.0
H704 L80	124.2	112.0	112.0	114.0	120.0	118.0	115.0	109.0	104.0
H705 L40	136.4	130.0	133.0	126.0	128.0	123.0	118.0	112.0	112.0
H705 L50	134.2	128.0	130.0	124.0	127.0	122.0	119.0	113.0	112.0
H705 L60	128.9	122.0	122.0	119.0	122.0	121.0	118.0	112.0	110.0
H705 L70	127.9	117.0	118.0	117.0	122.0	122.0	120.0	113.0	110.0
H705 L80	124.9	112.0	112.0	115.0	121.0	119.0	115.0	109.0	105.0
H1125L40	127.5	122.0	124.0	117.0	119.0	112.0	107.0	99.0	102.0
H1125L50	125.3	120.0	122.0	113.0	116.0	111.0	108.0	100.0	100.0
H1125L60	121.0	116.0	115.0	110.0	114.0	111.0	107.0	100.0	-0.0
H1125L70	117.5	111.0	110.0	106.0	112.0	110.0	105.0	100.0	94.0
H1125L80	113.9	108.0	106.0	103.0	108.0	106.0	102.0	97.0	91.0
H1126L40	133.6	127.0	130.0	123.0	126.0	121.0	117.0	111.0	111.0
H1126L50	133.9	126.0	129.0	123.0	128.0	124.0	121.0	116.0	113.0
H1126L60	129.1	122.0	123.0	119.0	123.0	120.0	118.0	112.0	106.0
H1126L70	125.5	117.0	117.0	113.0	120.0	119.0	116.0	111.0	106.0
H1126L80	121.4	113.0	112.0	110.0	116.0	115.0	112.0	107.0	100.0
H1127L40	135.3	129.0	132.0	124.0	127.0	122.0	118.0	112.0	112.0
H1127L50	135.4	127.0	130.0	125.0	130.0	125.0	123.0	118.0	115.0
H1127L60	130.7	123.0	124.0	121.0	125.0	122.0	119.0	114.0	109.0
H1127L70	127.9	119.0	118.0	116.0	122.0	122.0	119.0	114.0	109.0
H1127L80	123.6	114.0	113.0	112.0	118.0	118.0	115.0	110.0	-0.0

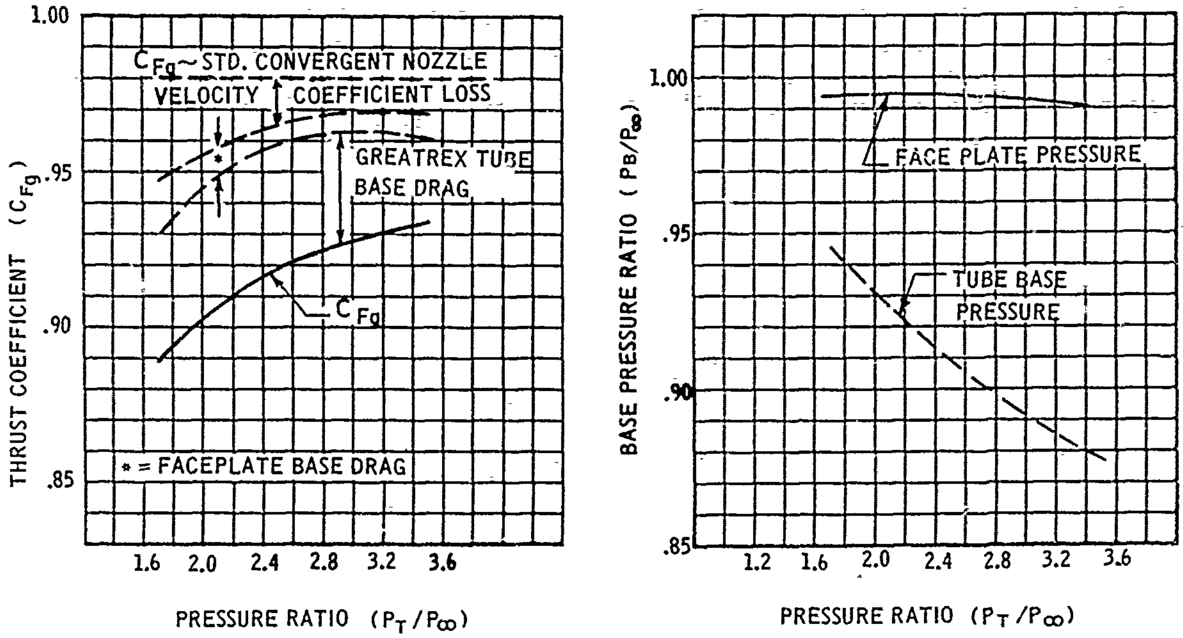
NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

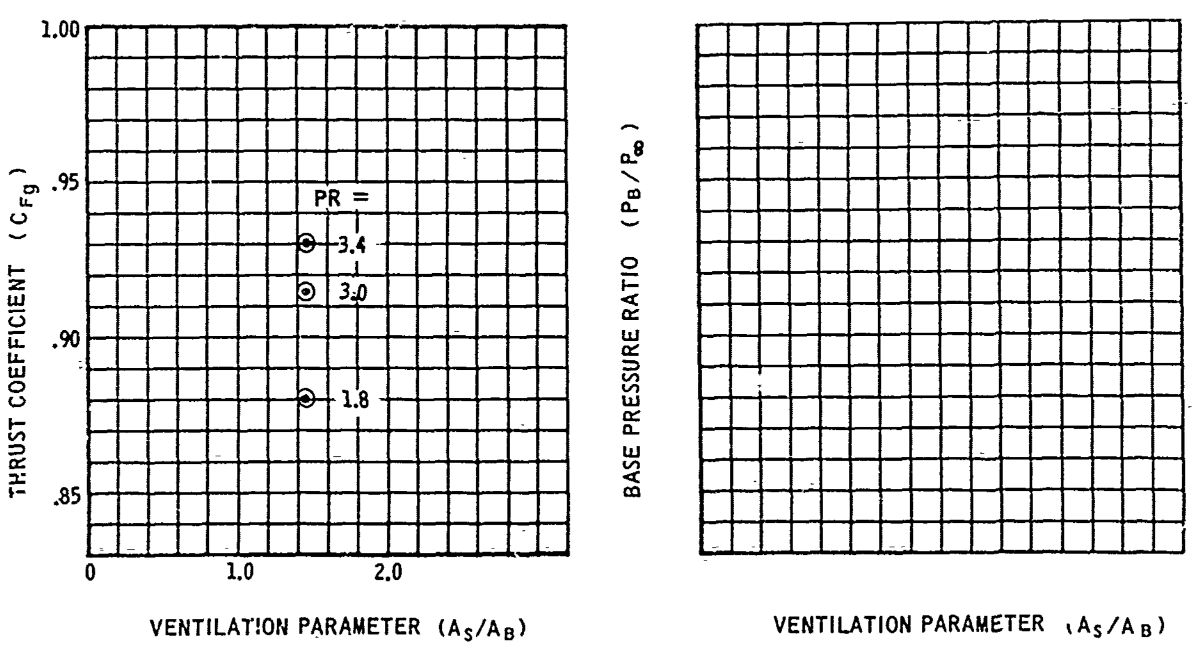
HM-AP-18



$$C_{Fg} = \frac{\text{(THRUST–DRAG) MEASURED}}{\text{IDEAL PRIMARY THRUST}}$$

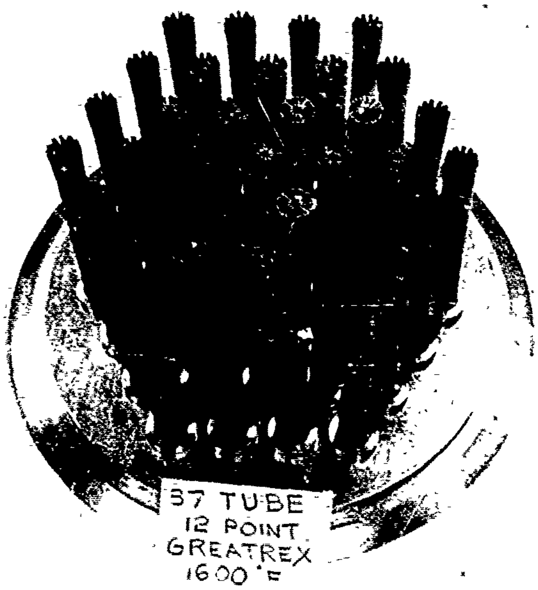
$$C_D = \frac{\text{(MASS FLOW) MEASURED}}{\text{IDEAL PRIMARY MASS FLOW}}$$





HM-AP-18a NOZZLE

(37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY AR=8.0)



Description:

The HM-AP-18a nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have 12 spoke nozzle terminations. The tubes were inserted in a 17-inch diameter baseplate and were removeable.

Number of Elements: 37 tubes with 12 spoke ends

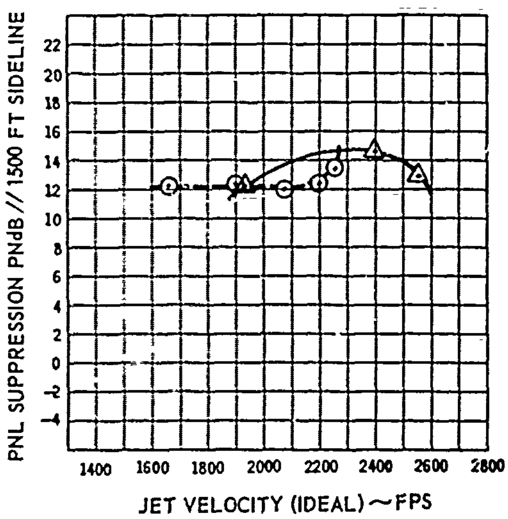
Area Ratio: 8.0

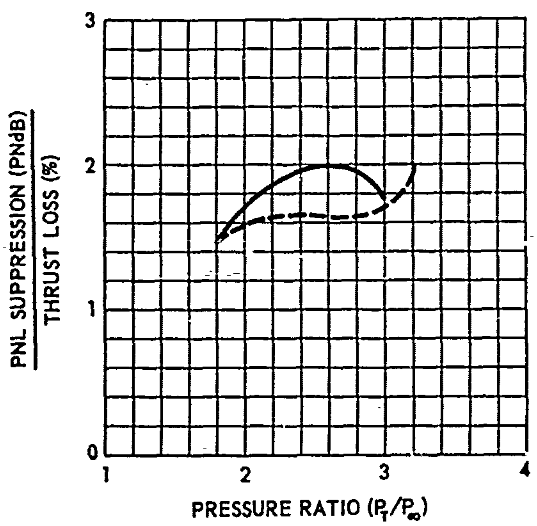
Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees

Length of Tubes:
- 7 inches
- 12 spoke terminations, AR = 1.86
- Flow area = 0.357 square inches
- Exit cant angle = 0 degrees
- Ventilation gutter angle = 77 degrees
- Spoke Penetration = 75%

Material: 321 CRES



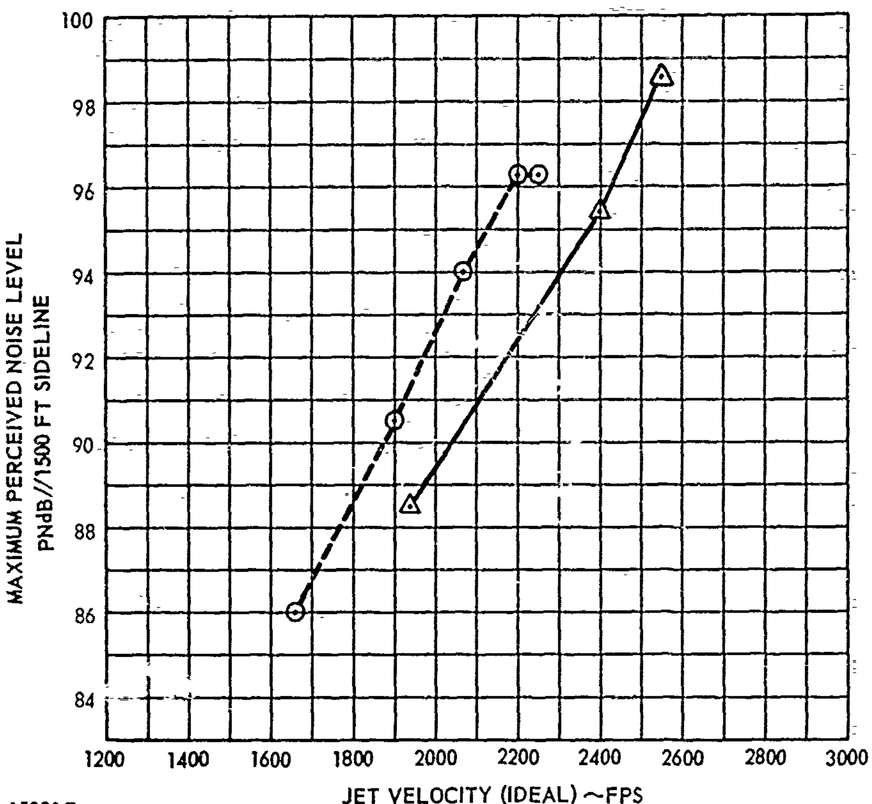


△—△ 1500° F
⊙---⊙ 1000° F

NOZZLE EXIT AREA (A_8): 5.9 FT^2

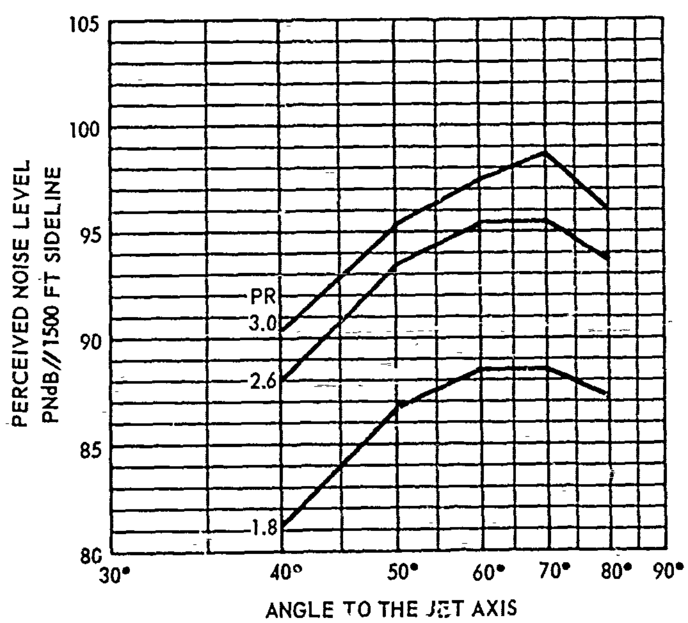
DATA INCLUDES GROUND REFLECTION INTERFERENCE.

HM-AP-18a NOZZLE
(37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY)
AR 8.0
SCALE FACTOR: 8:1



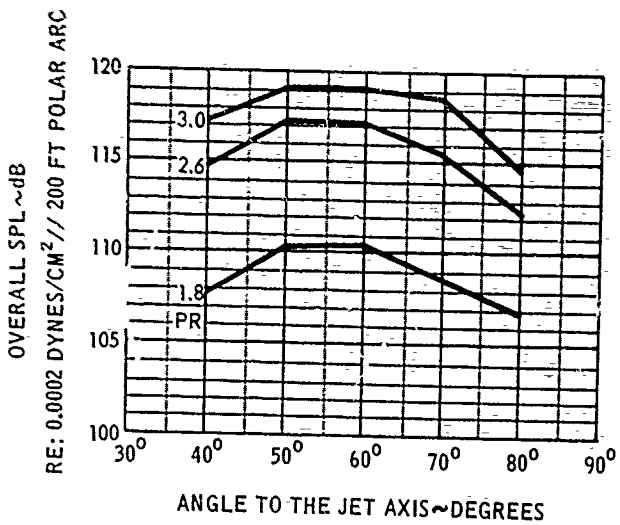
△—△ 1500° F
⊙---⊙ 1000° F

NOZZLE EXIT AREA (A_8): 5.9 FT^2

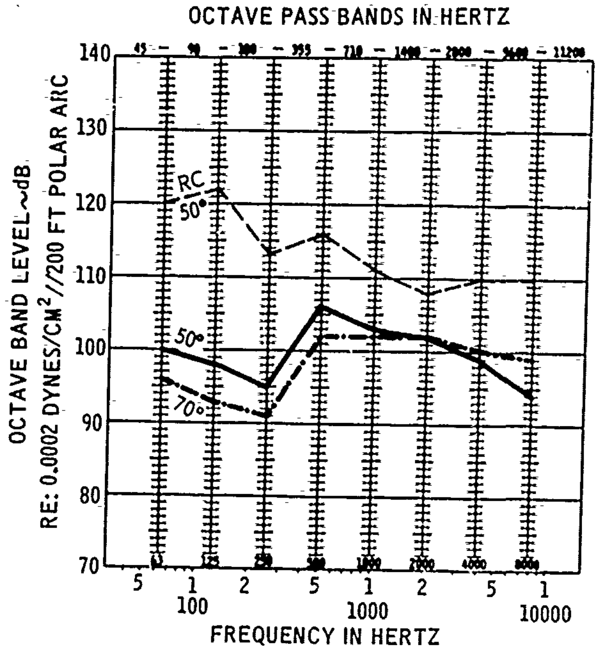


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

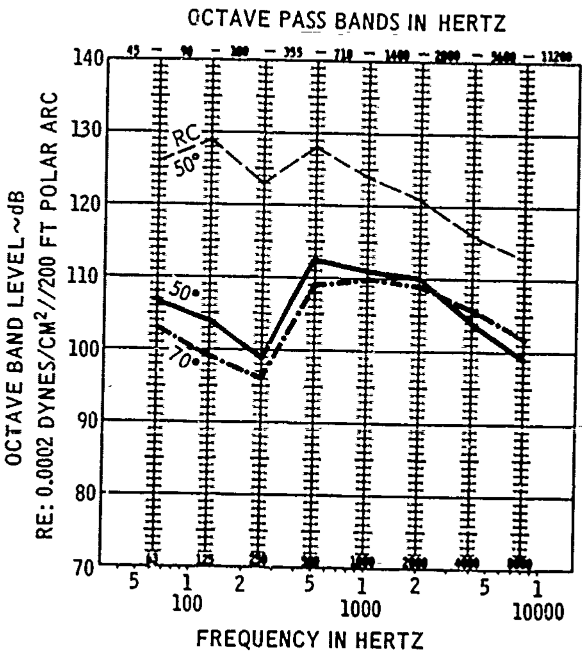


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

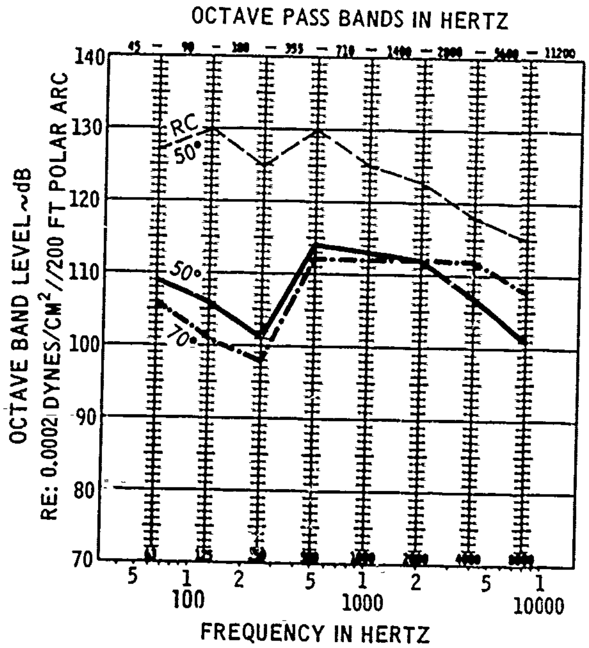


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1930 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

HM-AP-18a NOZZLE
(37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY)
AR 8.0
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2400 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2550 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-18a

(37 Tube, 12 Spoke Ends, Hexagonal Array, AR 8.0)

Remarks

The HM-AP-18a nozzle was the largest area ratio nozzle of the 37 tube hexagonal array test series. Nozzles tested with the 12-spoke terminations on each of the 37 tubes were:

HM-AP-18	AR 4.64
HM-AP-18a	AR 8.0
HM-AP-40	AR 3.33
HM-AP-41	AR 4.0
HM-AP-42	AR 5.2

Test results for the HM-AP-18a nozzle are discussed in References D7, D8 and D9. Least PNL suppression was attained with this nozzle. The large area ratio provided good low frequency suppression, however the high frequency portion of the spectrum was relatively high in level. Spacing the tube elements relatively far apart reduces the effectiveness of the outer rows of jets to shield the noise generated by the tubes in the inner rows, and jet mixing noise levels are higher.

HM-AP-18a

Test Facility: Annex L (Cell #1)
Nozzle and Microphone Heights are 20 Inches

Date:

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H 596	1.8	1000°F	1660 fps	HM-AP-18a
H 597	2.2	"	1900	"
H 598	2.6	"	2070	"
H 599	3.0	"	2200	"
H 600	3.2	"	2250	"
H1134	1.8	1500°F	1930	"
H1135	2.6	"	2400	"
H1136	3.0	"	2550	"
H 637	1.8	100°F	1660 fps	4.1-Inch Round Convergent Nozzle
H 638	2.2	"	1900	"
H 639	2.6	"	2070	"
H 640	3.0	"	2200	"
H 641	3.2	"	2250	"
H1125	1.8	1500°F	1930	"
H1126	2.6	"	2400	"
H1127	3.0	"	2550	"

Note: Measured acoustic data is recorded in Reference D2.

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES /CM^2//25 FT

HM-AP-18a

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H596 L40	106.3	101.0	99.0	93.0	100.0	97.0	94.0	94.0	-0.0
H596 L50	109.5	102.5	100.0	95.0	103.5	102.0	100.5	98.0	93.0
H596 L60	107.6	99.0	97.0	93.0	101.0	100.5	100.5	98.0	89.0
H596 L70	105.2	98.0	94.0	90.0	98.0	97.0	98.0	97.0	89.0
H596 L80	103.3	95.0	91.0	90.0	95.0	95.0	97.0	96.0	88.0
H597 L40	110.4	103.0	102.0	97.0	105.0	103.0	99.0	99.0	94.0
H597 L50	113.7	105.5	103.5	98.0	108.5	106.5	105.5	101.5	96.0
H597 L60	112.1	102.5	100.5	96.0	105.5	105.5	105.5	103.0	95.0
H597 L70	109.2	102.0	97.0	94.0	102.0	101.0	102.0	101.0	94.0
H597 L80	107.8	98.0	94.0	93.0	100.5	100.5	101.0	101.0	92.0
H598 L40	113.7	105.0	103.0	98.0	110.0	106.0	103.0	102.0	94.0
H598 L50	116.1	108.0	104.5	101.0	111.5	108.5	107.5	104.5	98.0
H598 L60	115.0	104.5	102.5	98.0	109.5	108.0	109.0	104.5	96.0
H598 L70	112.5	103.5	99.0	96.0	105.5	105.5	106.5	103.5	96.0
H598 L80	110.0	100.5	96.0	95.0	103.0	102.5	103.0	103.0	95.0
H599 L40	115.6	107.0	103.0	101.0	111.0	109.0	106.0	104.0	93.0
H599 L50	118.5	109.5	107.0	102.5	113.5	111.5	110.5	107.5	102.5
H599 L60	117.6	107.0	104.0	100.5	111.5	111.5	111.5	107.5	99.0
H599 L70	114.5	105.5	101.5	97.0	107.5	107.5	108.5	103.5	99.0
H599 L80	112.6	103.0	98.0	96.0	105.0	105.5	106.5	105.5	97.0
H600 L40	116.3	108.0	105.0	101.0	111.0	110.0	107.0	106.0	99.0
H600 L50	118.9	111.0	108.5	103.5	113.0	111.5	111.5	107.5	103.5
H600 L60	117.9	107.0	105.5	101.5	112.5	112.0	111.0	107.0	99.0
H600 L70	115.3	107.0	102.5	98.5	108.0	108.0	109.0	107.0	100.0
H600 L80	113.7	103.5	99.0	97.0	106.0	107.0	107.5	106.5	98.0
H1134L40	107.6	98.0	97.0	94.0	103.0	100.0	99.0	96.0	93.0
H1134L50	110.2	100.0	98.0	95.0	106.0	103.0	102.0	99.0	94.0
H1134L60	110.3	98.0	95.0	95.0	105.0	105.0	103.0	100.0	94.0
H1134L70	108.6	96.0	93.0	91.0	102.0	102.0	102.0	100.0	99.0
H1134L80	105.9	94.0	91.0	89.0	99.0	99.0	100.0	98.0	93.0
H1135L40	114.6	[illegible]	101.0	98.0	110.0	108.0	107.0	102.0	98.0
H1135L50	117.1	106.5	104.0	99.0	112.5	111.0	110.0	104.0	99.0
H1135L60	117.1	104.0	101.0	100.0	112.0	112.0	110.0	106.0	100.0
H1135L70	115.4	103.0	99.0	96.0	109.0	110.0	109.0	106.0	102.0
H1135L80	112.3	100.0	96.0	94.0	105.0	106.0	107.0	104.0	98.0
H1136L40	117.1	108.0	102.0	99.5	112.0	111.0	110.0	104.0	100.0
H1136L50	119.1	109.0	106.0	101.0	114.0	113.0	112.0	107.0	101.0
H1136L60	119.1	107.0	103.0	102.0	114.0	114.0	112.0	107.0	102.0
H1136L70	118.8	106.0	101.0	98.0	112.0	112.0	112.0	112.0	108.0
H1136L80	114.6	103.0	98.0	96.0	107.0	109.0	109.0	106.0	100.0
H637 L40	126.1	120.5	124.0	112.5	113.0	104.0	97.5	92.0	-0.0
H637 L50	123.7	119.5	120.0	111.5	113.5	106.5	102.5	95.0	-0.0
H637 L60	118.6	113.0	114.0	108.0	112.0	106.5	100.5	93.0	-0.0
H637 L70	115.2	109.0	109.0	105.0	110.0	104.0	101.0	94.0	-0.0
H637 L80	112.2	105.5	106.0	103.5	106.5	101.5	98.0	93.0	-0.0
H638 L40	129.3	124.0	126.0	118.5	120.5	111.0	106.0	103.0	-0.0
H638 L50	127.6	122.0	124.0	116.5	119.5	112.5	109.5	103.5	-0.0
H638 L60	122.3	116.0	117.5	111.5	116.0	111.5	107.0	101.5	-0.0
H638 L70	119.2	112.0	112.0	109.0	114.0	110.0	108.0	102.0	-0.0
H638 L80	115.9	107.5	108.5	107.5	110.5	107.5	104.5	98.5	88.0
H639 L40	131.6	125.0	128.0	122.5	124.0	116.5	113.0	110.0	-0.0
H639 L50	130.4	124.0	127.0	120.5	122.0	116.0	114.5	109.5	-0.0
H639 L60	125.4	118.0	120.0	115.5	120.0	115.0	111.5	106.5	98.0
H639 L70	123.0	114.0	115.0	113.0	118.0	115.0	113.0	107.0	100.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

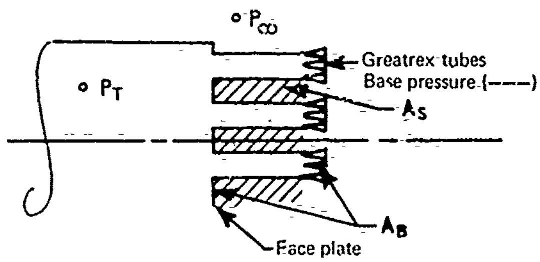
OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

HM–AP–18a

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H639 L80	120.1	110.0	110.5	111.5	[illegible]	113.5	110.5	105.5	97.0
H640 L40	133.6	127.0	130.0	124.0	126.0	119.5	115.0	113.0	107.5
H640 L50	132.9	126.0	129.0	123.0	126.0	119.0	118.5	113.5	109.5
H640 L60	127.8	120.5	122.0	117.0	122.0	118.5	115.5	110.0	101.5
H640 L70	125.6	115.0	117.0	117.0	120.0	118.0	117.0	111.0	104.0
H640 L80	123.0	111.5	112.5	114.5	118.0	116.5	113.5	109.5	101.5
H641 L40	135.5	128.0	132.0	127.0	128.0	121.0	117.0	113.0	108.5
H641 L50	134.2	127.0	130.0	124.0	128.0	121.5	119.0	114.5	110.5
H641 L60	128.7	121.0	123.0	119.0	123.0	119.0	116.5	112.0	-0.0
H641 L70	126.6	116.0	118.0	117.0	122.0	119.0	117.0	112.0	105.0
H641 L80	124.5	112.5	113.5	116.5	120.0	117.5	114.5	110.5	103.5
H1125L40	127.5	122.0	124.0	117.0	119.0	112.0	107.0	99.0	102.0
H1125L50	125.3	120.0	122.0	113.0	116.0	111.0	108.0	100.0	100.0
H1125L60	121.0	116.0	115.0	110.0	114.0	111.0	107.0	100.0	-0.0
H1125L70	117.5	111.0	110.0	106.0	112.0	110.0	105.0	100.0	94.0
H1125L80	113.9	108.0	106.0	103.0	108.0	106.0	102.0	97.0	91.0
H1126L40	133.6	127.0	130.0	123.0	126.0	121.0	117.0	111.0	111.0
H1126L50	133.9	126.0	129.0	133.0	128.0	124.0	121.0	116.0	113.0
H1126L60	129.1	122.0	123.0	119.0	123.0	120.0	118.0	112.0	106.0
H1126L70	125.5	117.0	117.0	113.0	120.0	119.0	116.0	111.0	106.0
H1126L80	121.4	113.0	112.0	110.0	116.0	115.0	112.0	107.0	100.0
H1127L40	135.3	129.9	132.0	124.0	127.0	122.0	118.0	112.0	112.0
H1127L50	135.4	127.0	130.0	125.0	130.0	125.0	123.0	118.0	115.0
H1127L60	130.7	123.0	124.0	121.0	125.0	122.0	119.0	114.0	109.0
H1127L70	127.9	119.0	118.0	116.0	122.0	122.0	119.0	114.0	109.0
H1127L80	123.6	114.0	113.0	112.0	118.0	118.0	11 5.0	110.0	-0.0

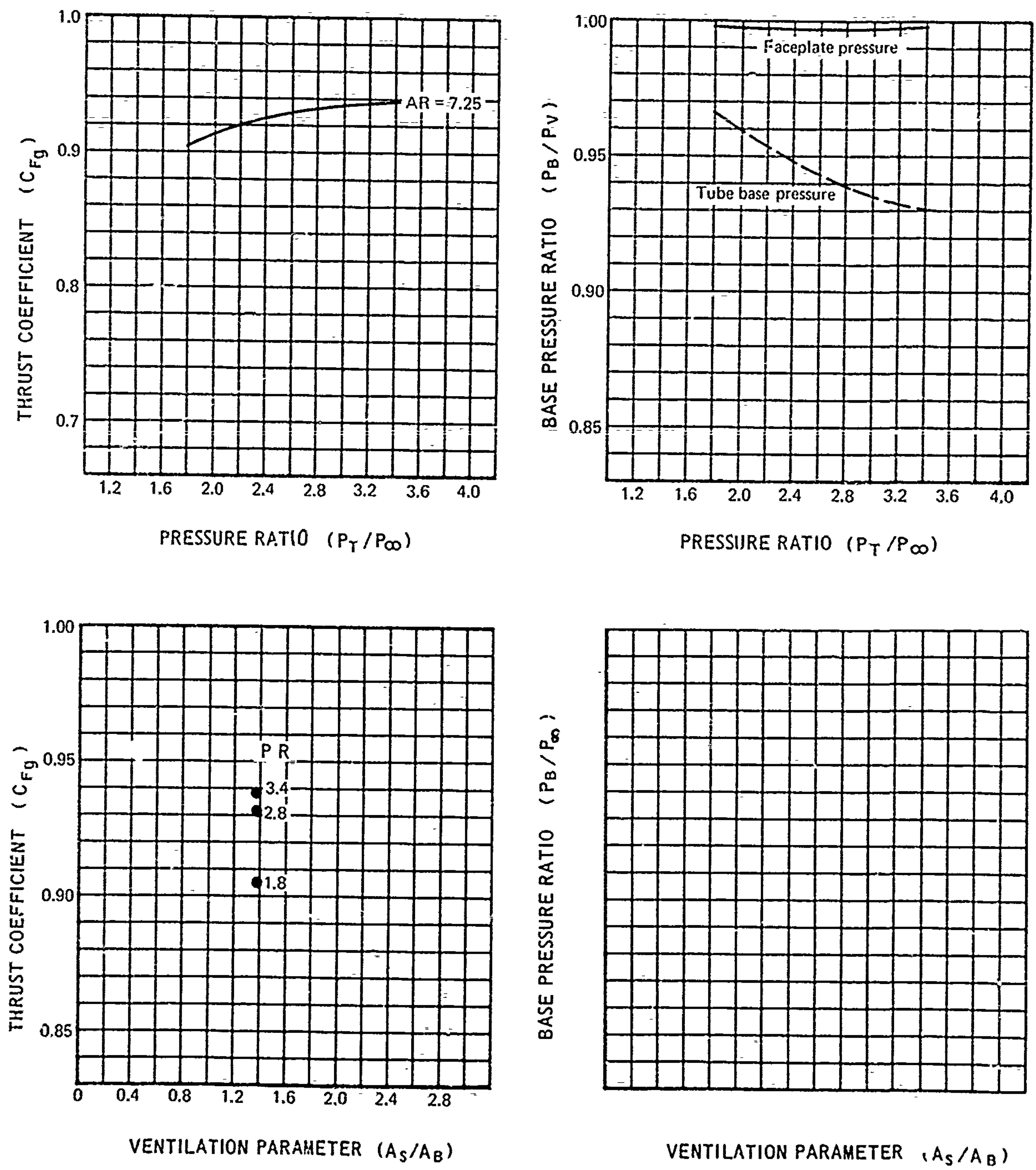
NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-18a



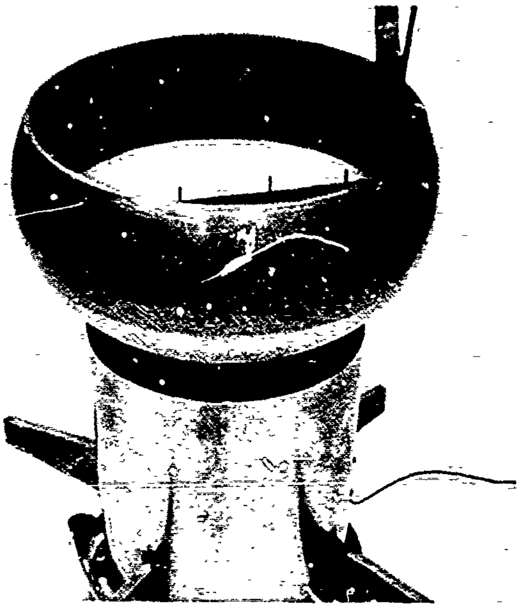
$$C_{Fg} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



HM-AP-20 NOZZLE

(ANNULAR SLOT WITH COANDA TYPE PLUG, AR 6.5)



Description:

The HM-AP-20 nozzle has an annular slot opening and center plug. Initially the primary flow is vectored outward 60 degrees relative to the nozzle axis. The center body was designed to gradually redirect the primary flow parallel to the nozzle axis by utilizing the "Coanda effect." Thrust is obtained largely from low static pressures on the plug.

Element: Annular Slot

Area Ratio: 6.5

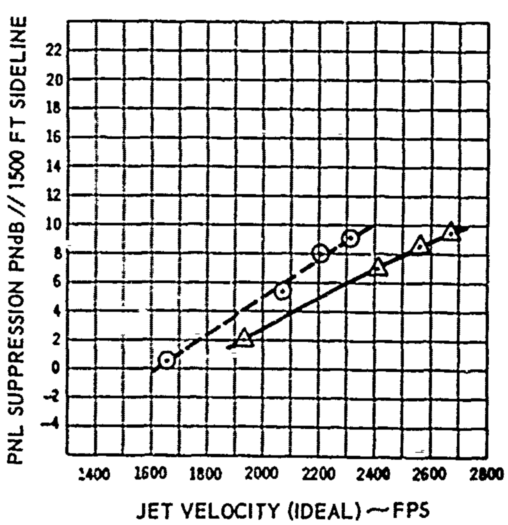
Flow Area: 11.4 Square Inches

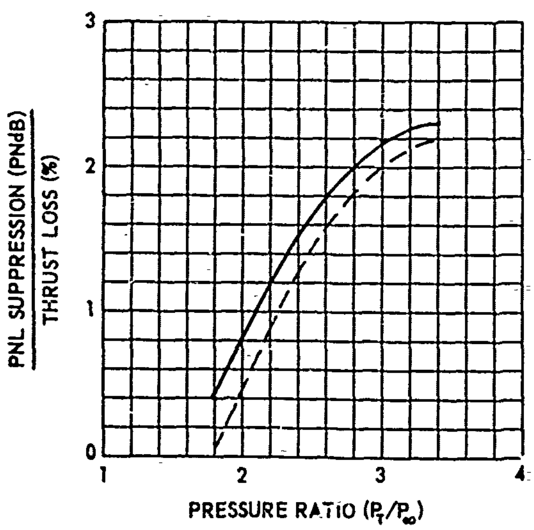
Exit Cant Angle: 60 Degrees Outward

Annular Slot Width: 0.56 Inches

Outside Diameter of Annular Slot: 7.8 Inches

Material: 321 CRES

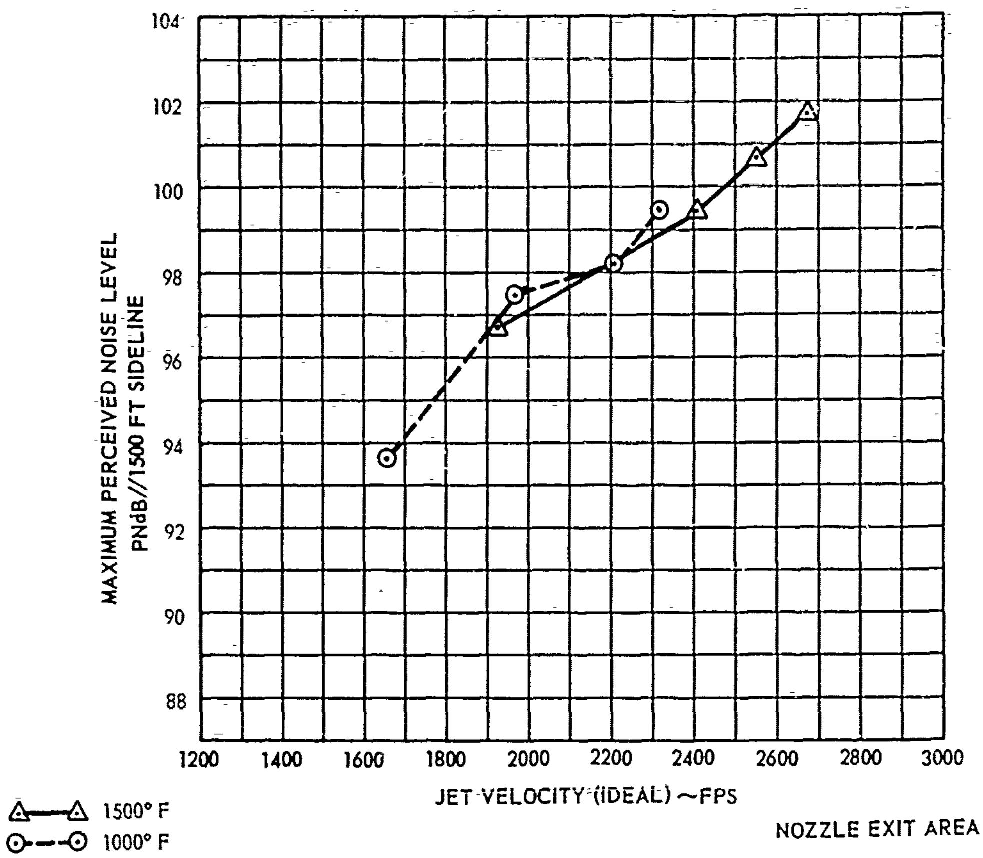




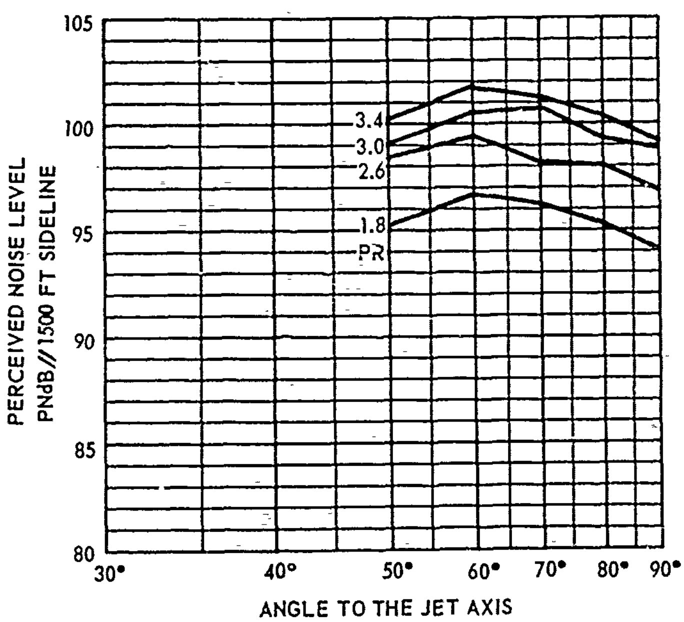
NOZZLE EXIT AREA (A_8): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-20 NOZZLE
(ANNULAR SLOT WITH 'COANDA TYPE' PLUG)
AR 6.5
SCALE FACTOR: 8:1



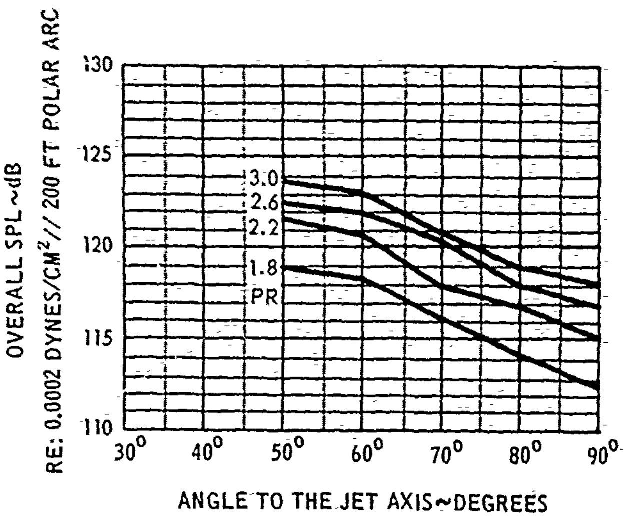
NOZZLE EXIT AREA (A_8): 3.3 FT^2



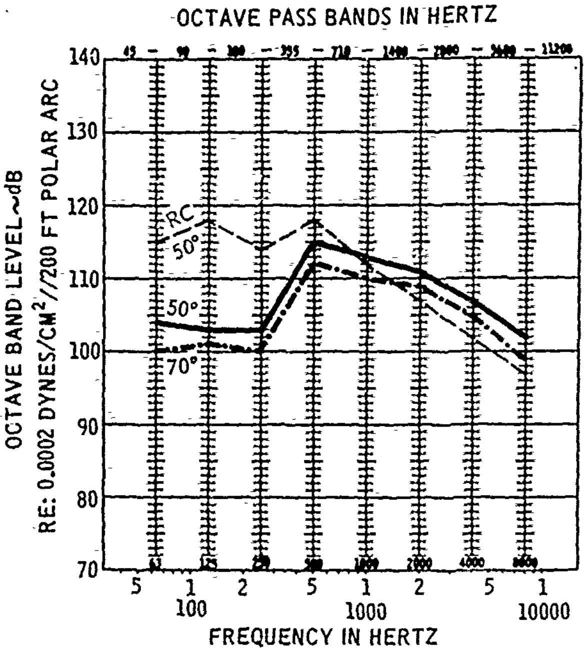
TOTAL TEMPERATURE (T_8): 1500° F

NOZZLE EXIT AREA (A_8): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

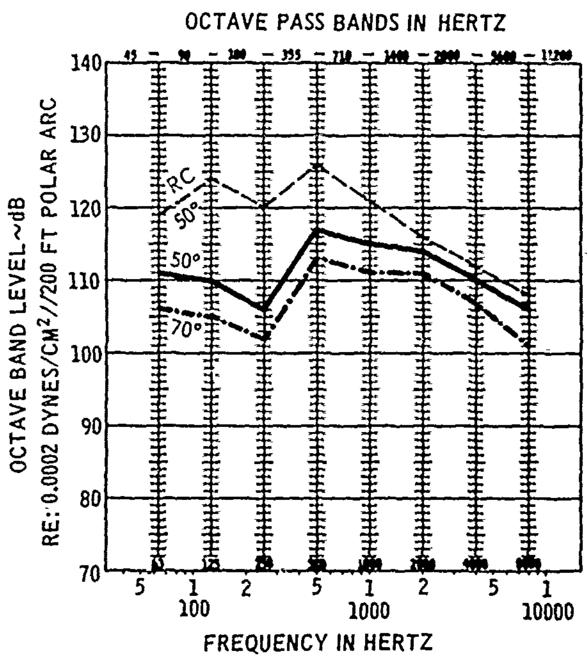


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 3.3 FT²

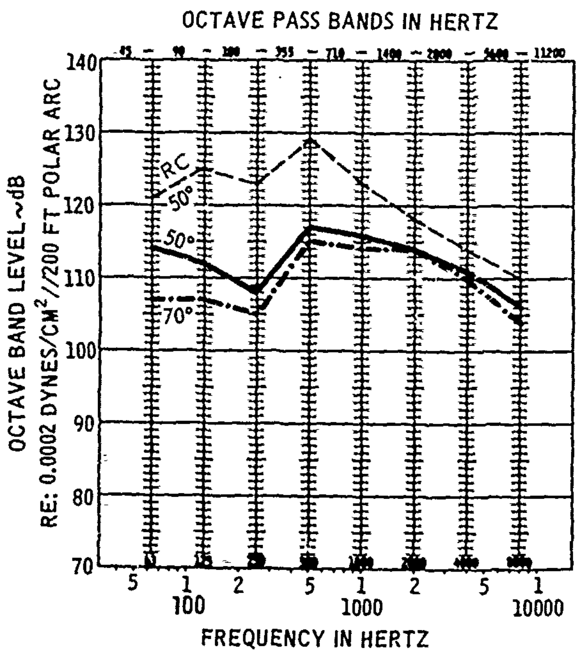


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²

HM-AP-20 NOZZLE
(ANNULAR SLOT WITH 'COANDA TYPE' PLUG)
AR 6:5
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-20 NOZZLE

(Annular Slot with "Coanda Type" Plug)

Remarks

Several configurations of the HM-AP-20 Nozzle were tested with acoustic-absorbent-lined and unlined ejectors. The unlined ejector configuration did not affect perceived noise level (PNdB) suppression values relative to the nozzle configuration without ejector. A fiberglass lined ejector configurati improved suppression values by 2 to 5 PNdB at low pressure ratios, PR = 1.8 and 2.6 at $T_T = 1500^{\circ}F$, however no improvement in suppression was noted for pressure ratios over 2.6. See Reference D10.

HM-AP-20 NOZZLE

Test Facility: Annex D (Cell #1)
Nozzle and Microphone Height is 20 Inches

Date: February 15, 1968

T_{amb}: 58°F

R.H.: 33%

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
2440	1.8	1000°F	1659 fps	HM-AP-20
2441	2.6	"	2073	"
2442	3.0	"	2205	"
2443	3.4	"	2311	"
2444	1.8	1500°F	1923	"
2445	2.6	"	2402	"
2446	3.0	"	2555	"
2447	3.4	"	2678	"
2432	1.8	1000°F	1659 fps	3.08 Inch Round Convergent Nozzle
2433	2.6	"	2073	"
2434	3.0	"	2205	"
2435	3.4	"	2311	"
2436	1.8	1500°F	1923	"
2437	2.6	"	2402	"
2438	3.0	"	2555	"
2439	3.4	"	2678	"

HM-AP-20 NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
2440 L50	115.9	103.0	99.0	99.0	112.0	110.0	108.0	104.0	[illegible]
2440 L60	115.4	99.0	99.0	96.0	111.0	110.0	108.0	105.0	[illegible]
2440 L70	112.[illegible]	100.0	97.0	97.0	108.0	107.0	105.0	102.0	95.0
2440 L80	110.7	95.0	96.0	95.0	106.0	104.0	104.0	101.0	90.0
2440 L90	108.3	94.0	96.0	95.0	103.0	101.0	102.0	99.0	93.0
2441 L50	119.5	108.0	107.0	104.0	114.0	114.0	112.0	108.0	104.0
2441 L60	118.5	105.0	107.0	103.0	113.0	113.0	112.0	109.0	104.0
2441 L70	117.[illegible]	102.0	104.0	100.0	112.0	110.0	111.0	107.0	101.0
2441 L80	115.2	100.0	102.0	99.0	110.0	109.0	108.0	106.0	102.0
2441 L90	113.2	100.0	100.0	99.0	107.0	106.0	107.0	105.0	100.0
2442 L50	119.4	110.0	109.0	105.0	114.0	114.0	112.0	108.0	104.0
2442 L60	119.2	106.0	108.0	104.0	113.0	113.0	113.0	109.0	105.0
2442 L70	117.7	104.0	105.0	102.0	112.0	112.0	111.0	108.0	106.0
2442 L80	116.[illegible]	102.0	103.0	100.0	110.0	109.0	110.0	107.0	104.0
2442 L90	114.5	101.0	102.0	100.0	107.0	107.0	109.0	107.0	102.0
2443 L50	121.3	112.0	111.0	107.0	116.0	115.0	113.0	109.0	105.0
2443 L60	120.[illegible]	108.0	109.0	106.0	115.0	114.0	114.0	110.0	108.0
2443 L70	118.9	105.0	106.0	103.0	114.0	113.0	112.0	108.0	103.0
2443 L80	117.1	103.0	104.0	102.0	111.0	111.0	110.0	108.0	104.0
2443 L90	115.7	102.0	103.0	101.0	109.0	108.0	110.0	108.0	102.0
2444 L50	118.2	104.0	103.0	103.0	115.0	113.0	111.0	107.0	102.0
2444 L60	118.4	103.0	102.0	102.0	114.0	113.0	111.0	107.0	103.0
2444 L70	116.1	100.0	101.0	100.0	112.0	110.0	109.0	105.0	99.0
2444 L80	114.1	98.0	99.0	98.0	110.0	107.0	107.0	104.0	100.0
2444 L90	112.5	97.0	99.0	98.0	108.0	105.0	106.0	103.0	97.0
2445 L50	121.7	111.0	110.0	106.0	117.0	115.0	114.0	110.0	108.0
2445 L60	120.[illegible]	108.0	109.0	105.0	115.0	11[illegible].0	114.0	110.0	106.0
2445 L70	117.[illegible]	106.0	105.0	102.0	113.0	111.0	111.0	107.0	101.0
2445 L80	116.[illegible]	103.0	103.0	101.0	112.0	110.0	110.0	107.0	103.0
2445 L90	115.[illegible]	101.0	102.0	101.0	109.0	105.0	109.0	106.0	101.0
2446 L50	122.5	114.0	112.0	108.0	117.0	115.0	114.0	111.0	105.0
2446 L60	122.[illegible]	111.0	111.0	107.0	116.0	116.0	115.0	111.0	107.0
2446 L70	120.3	107.0	107.0	105.0	115.0	114.0	114.0	110.0	104.0
2446 L80	117.9	105.0	105.0	102.0	113.0	111.0	111.0	108.0	104.0
2446 L90	116.9	103.0	104.0	102.0	110.0	110.0	111.0	109.0	103.0
2447 L50	123.8	116.0	114.0	110.0	118.0	117.0	115.0	111.0	107.0
2447 L60	123.2	112.0	112.0	109.0	118.0	117.0	115.0	112.0	108.0
2447 L70	120.9	108.0	109.0	106.0	115.0	115.0	114.0	111.0	106.0
2447 L80	118.9	105.0	106.0	104.0	114.0	112.0	112.0	109.0	105.0
2447 L90	117.1	105.0	105.0	103.0	110.0	110.0	111.0	109.0	103.0
2432 L40	120.4	113.0	117.0	110.0	114.0	106.0	100.0	96.0	92.0
2432 L50	118.6	111.0	115.0	108.0	112.0	107.0	100.0	96.0	91.0
2432 L60	114.7	106.0	109.0	103.0	110.0	105.0	102.0	96.0	92.0
2432 L70	110.7	101.0	103.0	100.0	106.0	103.0	100.0	97.0	90.0
2432 L80	110.1	106.0	99.0	97.0	104.0	101.0	99.0	95.0	89.0
2433 L40	127.[illegible]	118.0	122.0	117.0	124.0	117.0	113.0	109.0	104.0
2433 L50	127.1	117.0	121.0	117.0	123.0	118.0	112.0	109.0	105.0
2433 L60	121.8	111.0	114.0	111.0	118.0	113.0	111.0	107.0	100.0
2433 L70	118.2	109.0	108.0	106.0	113.0	111.0	110.0	106.0	101.0
2433 L80	116.4	103.0	105.0	104.0	112.0	110.0	108.0	105.0	96.0
2434 L40	129.1	121.0	124.0	119.0	124.0	118.0	115.0	111.0	105.0
2434 L50	129.[illegible]	119.0	123.0	120.0	126.0	121.0	116.0	112.0	108.0
2434 L60	124.0	113.0	116.0	113.0	120.0	11[illegible].0	114.0	110.0	103.0
2434 L70	120.[illegible]	108.0	110.0	110.0	115.0	114.0	113.0	109.0	105.0
2434 L80	118.9	105.0	106.0	107.0	114.0	113.0	111.0	107.0	101.0
2435 L40	130.[illegible]	122.0	126.0	121.0	125.0	119.0	115.0	112.0	107.0
2435 L50	131.4	121.0	125.0	122.0	128.0	123.0	118.0	114.0	110.0
2435 L60	125.[illegible]	114.0	118.0	115.0	122.0	117.0	116.0	112.0	105.0
2435 L70	122.[illegible]	109.0	111.0	114.0	117.0	117.0	115.0	111.0	107.0
2435 L80	121.7	106.0	108.0	114.0	117.0	115.0	113.0	110.0	103.0

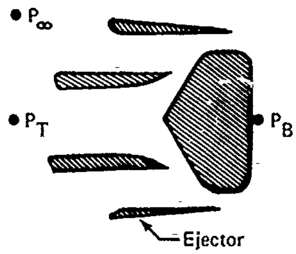
NOTE: THIS DATA INLUDES GROUND REFLECTION INTERFERENCE

HM-AP-20 NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
2436 L40	124.3	115.0	119.0	114.0	120.0	113.0	109.0	103.0	99.0
2436 L50	123.1	115.0	118.0	114.0	118.0	112.0	107.0	102.0	97.0
2436 L60	118.6	109.0	113.0	108.0	114.0	109.0	106.0	100.0	93.0
2436 L70	114.5	104.0	107.0	103.0	110.0	106.0	105.0	100.0	94.0
2436 L80	111.9	101.0	103.0	101.0	108.0	104.0	102.0	98.0	90.0
2437 L40	128.1	120.0	123.0	118.0	123.0	117.0	114.0	109.0	105.0
2437 L50	130.1	119.0	124.0	120.0	126.0	121.0	116.0	112.0	108.0
2437 L60	125.1	114.0	118.0	115.0	121.0	116.0	114.0	110.0	103.0
2437 L70	120.6	108.0	111.0	109.0	116.0	114.0	112.0	108.0	103.0
2437 L80	117.7	105.0	107.0	106.0	113.0	111.0	110.0	106.0	99.0
2438 L40	129.8	122.0	125.0	121.0	124.0	118.0	113.0	111.0	105.0
2438 L50	132.4	121.0	125.0	123.0	129.0	123.0	118.0	114.0	110.0
2438 L60	128.3	116.0	120.0	117.0	125.0	120.0	117.0	112.0	106.0
2438 L70	122.9	110.0	113.0	111.0	118.0	116.0	115.0	111.0	106.0
2438 L80	120.9	107.0	109.0	109.0	116.0	115.0	113.0	109.0	103.0
2439 L40	131.2	124.0	127.0	121.0	125.0	119.0	115.0	111.0	107.0
2439 L50	133.3	123.0	127.0	124.0	129.0	124.0	119.0	115.0	111.0
2439 L60	128.6	117.0	121.0	118.0	125.0	120.0	117.0	113.0	107.0
2439 L70	124.1	111.0	114.0	112.0	119.0	118.0	116.0	112.0	108.0
2439 L80	122.0	108.0	110.0	110.0	117.0	116.0	114.0	111.0	105.0

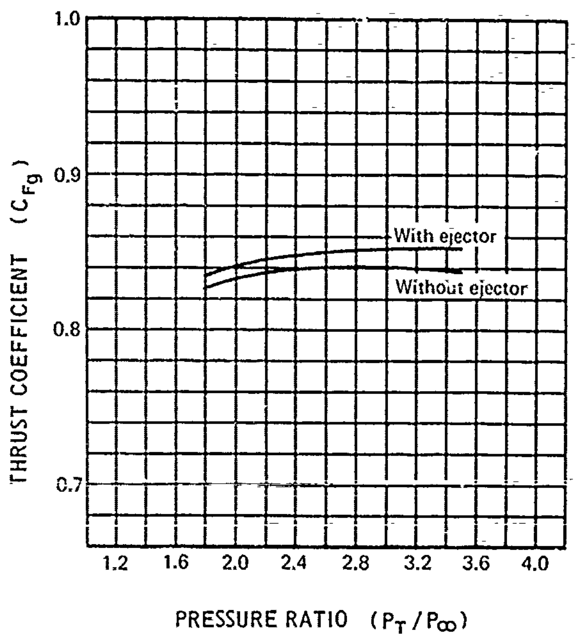
NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

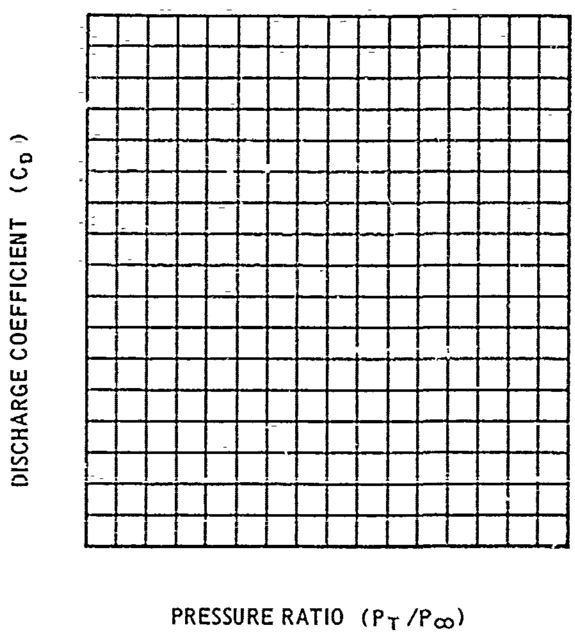
HM-AP-20

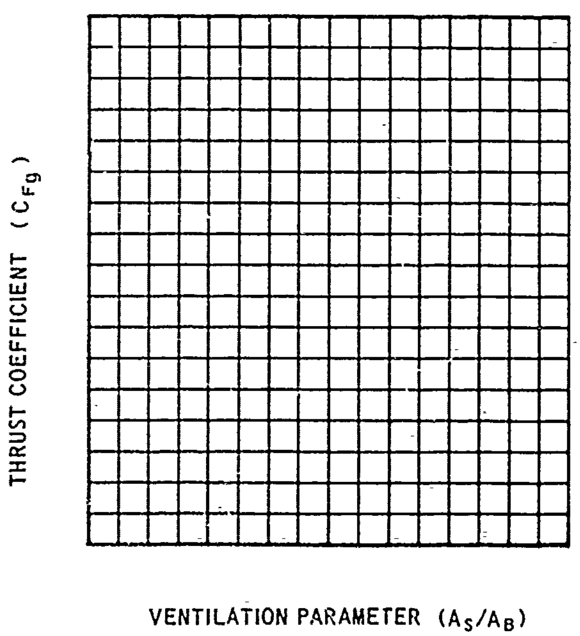


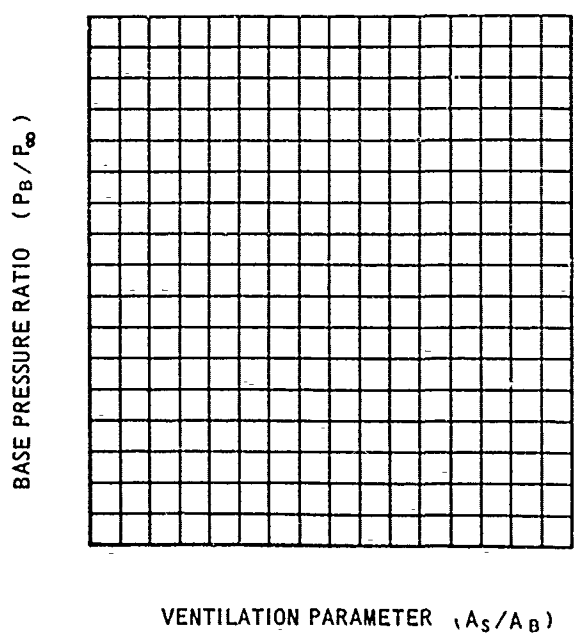
$$C_{Fg} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



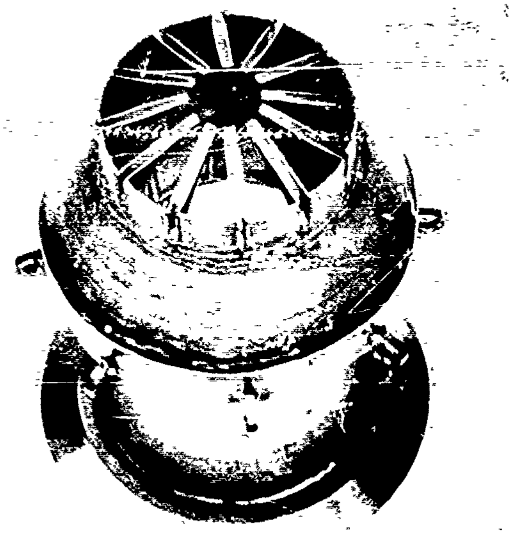






HM-AP-22 NOZZLE

(12 SPOKES, AR 1.4)



Description:

Number of Elements: 12 spokes

Area Ratio: 1.4

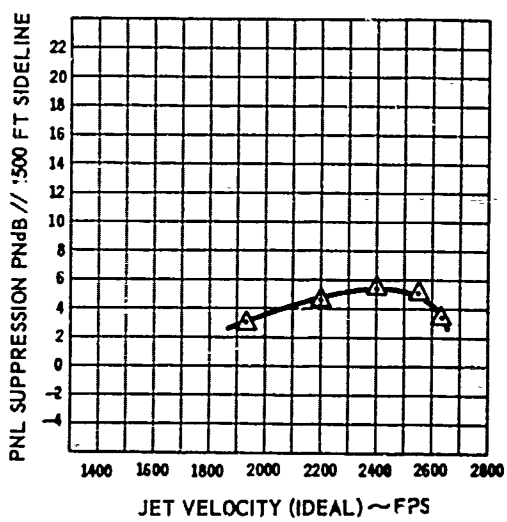
Spoke Penetration: 70%

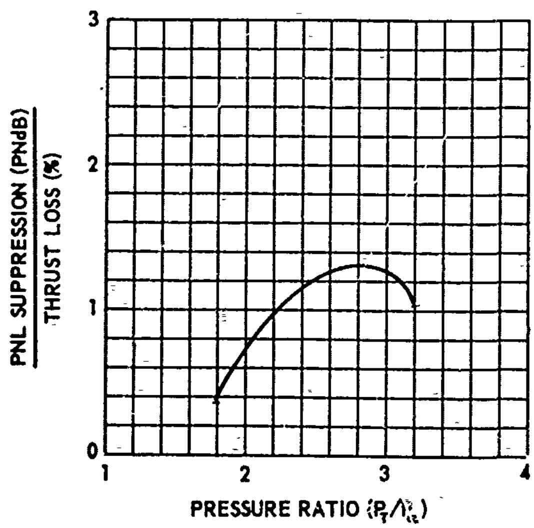
Flow Area: $\simeq$ 13.2 square inches

Exit Cant Angle: 17.5° outward

Ventilation Gutter Cant Angle: 27.5°

Nozzle Diameter: 4.62 inches



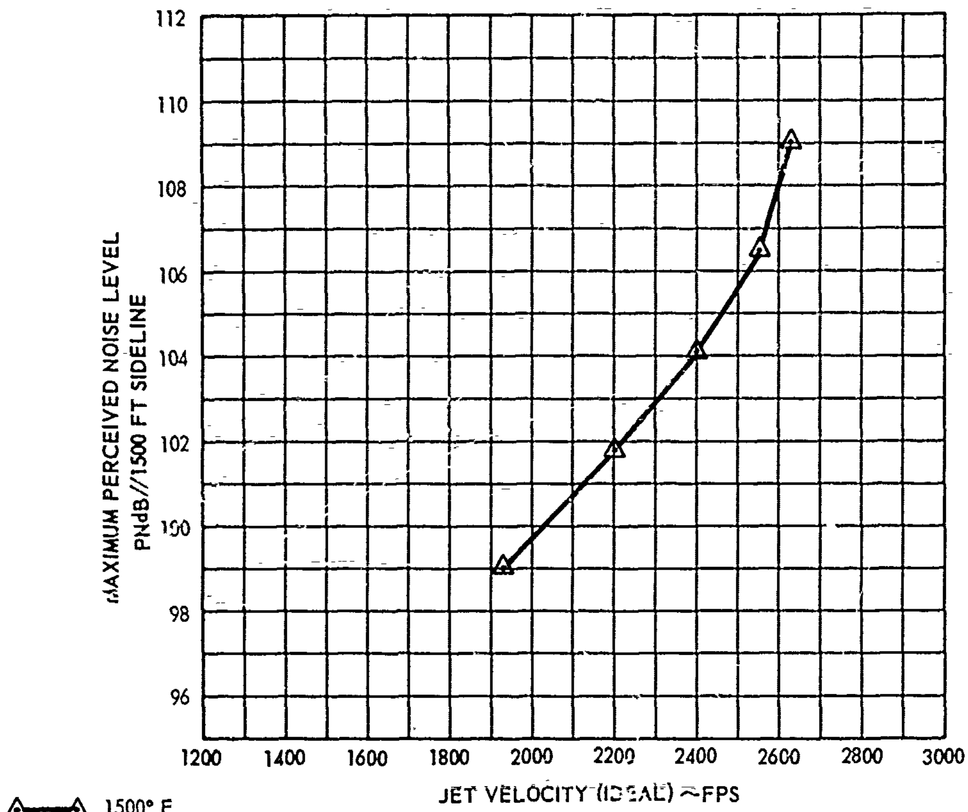


△—△ 1500° F

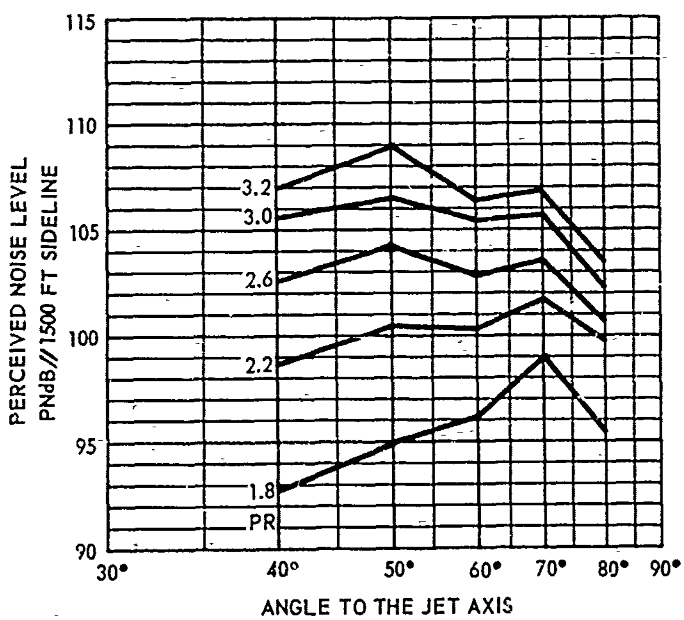
NOZZLE EXIT AREA (A_e): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-22 NOZZLE
(12 SPOKES)
AR 1.4
SCALE FACTOR: 8:1



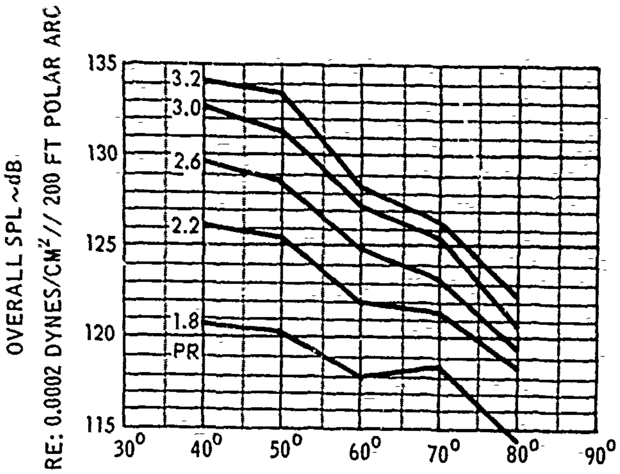
NOZZLE EXIT AREA (A_8): 5.9 FT^2



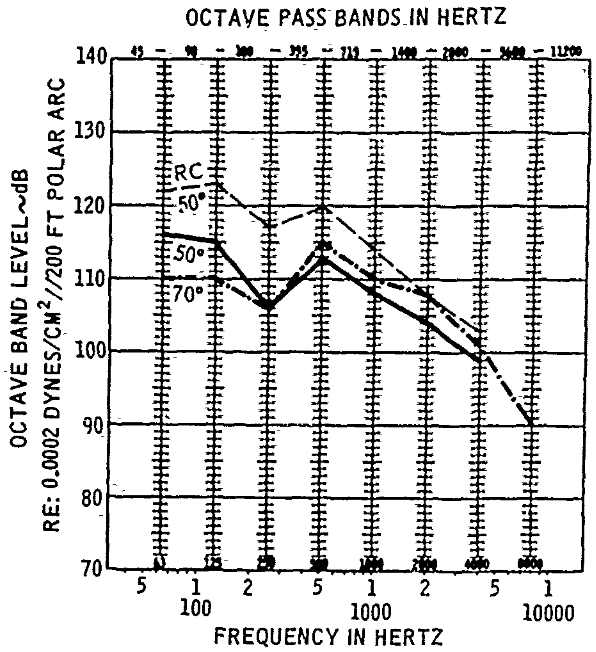
TOTAL TEMPERATURE (T_8): 1500° F

NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

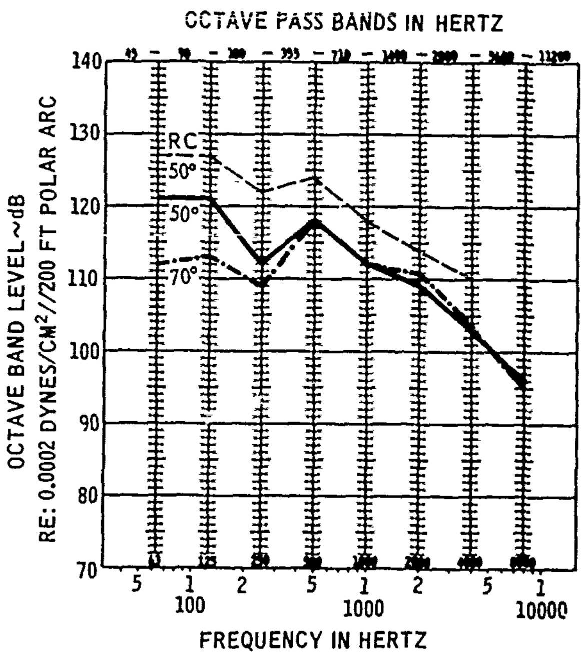


ANGLE TO THE JET AXIS~DEGREES
TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

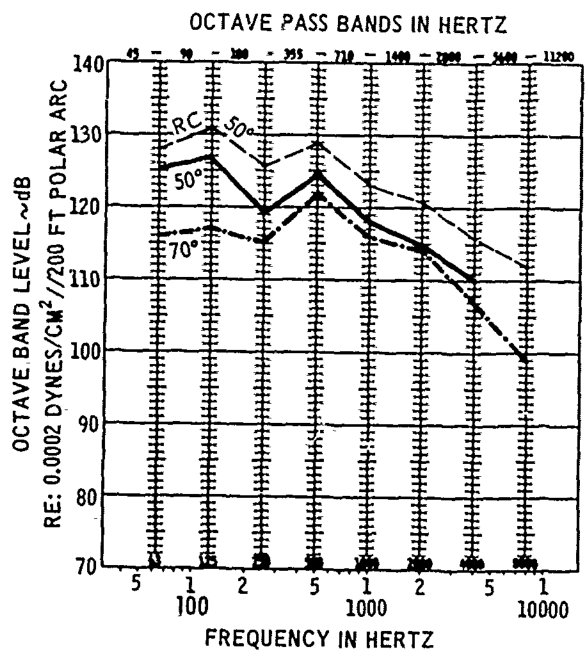


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

HM-AP-22 NOZZLE
(12 SPOKES)
AR 1.4
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-22
(12 Spokes, AR = 1.4)

Remarks

Several different chuted ejector configurations were tested on the HM-AP-22 nozzle. The chuted ejectors improved PNL suppression by as much as 3.5 PNdB, however, the attendant increase in thrust loss (approximately 25%) more than offset any advantages gained in suppression, see Reference D11.

HM-AP-22

Test Facility: Annex D (Cell #1)

Date:

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H 576	1.8	1500°F	1923 fps	HM-AP-22
H 577	2.2	"	2202	"
H 578	2.6	"	2402	"
H 579	3.0	"	2555	"
H 580	3.2	"	2610	"
H 561	1.8	1500°F	1923 fps	4.1-Inch Round Convergent Nozzle
H 562	2.2	"	2202	"
H 563	2.6	"	2402	"
H 564	3.0	"	2555	"
H 565	3.2	"	2610	"

Measured acoustic data is included in Reference D2.

NOZZLE TEST DATA

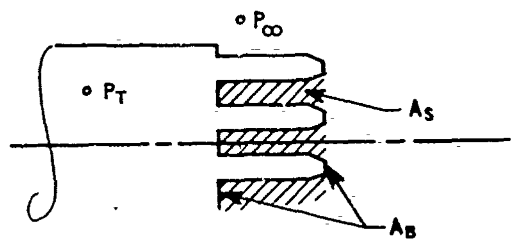
OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-22

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H576L40	120.8	117.0	117.0	106.0	111.0	105.0	100.0	95.0	0.0
H576L50	120.2	116.0	115.0	106.0	113.0	108.0	104.0	99.0	0.0
H576L60	118.0	112.0	111.0	107.0	113.0	108.0	105.0	97.0	86.0
H576L70	118.6	110.0	110.0	106.0	115.0	110.0	108.0	101.0	90.0
H576L80	114.3	106.0	106.0	103.0	108.0	107.0	106.0	102.0	89.0
H577L40	126.1	121.0	123.0	113.0	116.0	111.0	106.0	102.0	92.0
H577L50	125.5	121.0	121.0	112.0	118.0	112.0	109.0	103.0	96.0
H577L60	122.0	115.0	116.0	111.0	117.0	112.0	109.0	103.0	93.0
H577L70	121.4	112.0	113.0	109.0	118.0	112.0	111.0	104.0	95.0
H577L80	118.4	109.0	110.0	107.0	114.0	110.0	109.0	105.0	92.0
H578L40	129.7	124.0	126.0	119.5	122.0	115.0	110.0	106.5	0.0
H578L50	128.7	123.0	125.0	116.0	121.0	116.0	112.0	106.0	99.0
H578L60	124.9	118.0	119.0	113.0	120.0	115.0	110.0	104.0	95.0
H578L70	123.2	114.0	115.0	112.0	119.0	115.0	113.0	106.0	97.0
H578L80	119.4	111.0	111.0	108.0	115.0	111.0	109.0	105.0	95.0
H579L40	132.6	125.0	129.0	123.0	126.0	118.0	113.0	110.0	103.0
H579L50	131.2	125.0	127.0	119.0	125.0	118.0	115.0	110.0	0.0
H579L60	127.3	120.0	122.0	116.0	122.0	117.0	113.0	108.0	98.0
H579L70	125.5	116.0	117.0	115.0	122.0	116.0	114.0	107.0	99.0
H579L80	120.8	111.0	112.0	111.0	116.0	113.0	111.0	107.0	97.0
H580L40	134.1	127.0	130.0	125.0	128.0	119.5	115.0	110.0	103.0
H580L50	133.5	127.0	129.0	121.0	128.0	120.0	117.0	112.0	107.0
H580L60	128.3	121.0	123.0	117.0	123.0	118.0	114.0	109.0	93.0
H580L70	126.5	117.0	118.0	116.0	123.0	117.0	115.0	108.0	101.0
H580L80	122.3	113.0	114.0	113.0	117.0	115.0	112.0	108.0	98.0
H561L40	128.4	122.0	125.0	119.0	121.0	111.0	106.0	103.0	0.0
H561L50	127.3	122.0	123.0	117.0	120.0	114.0	108.0	103.0	0.0
H561L60	123.5	116.0	119.0	114.0	118.0	111.0	106.0	101.0	0.0
H561L70	120.5	113.0	113.0	111.0	116.0	111.0	107.0	101.0	0.0
H561L80	114.6	107.0	106.0	104.0	111.0	105.0	101.0	96.0	86.0
H562L40	131.9	126.0	128.0	122.0	124.0	118.0	113.0	110.0	0.0
H562L50	131.8	127.0	127.0	122.0	124.0	118.0	114.0	110.0	0.0
H562L60	127.1	119.0	122.0	118.0	122.0	115.0	112.0	106.0	98.0
H562L70	123.5	116.0	116.0	113.0	119.0	114.0	111.0	106.0	99.0
H562L80	118.9	109.0	111.0	109.0	115.0	110.0	108.0	103.0	0.0
H563L40	133.0	126.0	129.0	124.5	126.0	119.0	114.0	112.5	0.0
H563L50	134.6	128.0	130.0	125.0	128.0	122.0	119.0	116.0	111.5
H563L60	132.1	124.0	127.0	122.0	127.0	121.0	117.0	114.0	0.0
H563L70	125.4	116.0	118.0	115.0	121.0	116.0	115.0	110.0	103.0
H563L80	122.4	112.0	113.0	112.0	118.0	115.0	113.0	109.0	100.0
H564L40	134.6	128.0	121.0	125.0	127.0	121.0	117.0	114.0	108.0
H564L50	135.3	128.0	131.0	125.5	129.0	123.0	121.0	116.0	112.0
H564L60	131.2	123.0	126.0	121.0	126.0	120.0	118.0	113.0	0.0
H564L70	127.6	118.0	120.0	118.0	123.0	119.0	117.0	112.0	106.0
H564L80	123.6	113.0	114.0	113.0	119.0	117.0	114.0	110.0	103.0
H565L40	137.0	130.0	123.0	128.0	130.0	124.0	119.0	117.0	110.0
H565L50	135.7	128.0	131.0	126.0	130.0	124.0	121.0	118.0	114.0
H565L60	131.8	124.0	121.0	122.0	126.0	120.0	119.0	114.0	0.0
H565L70	128.4	118.0	121.0	118.0	124.0	120.0	118.0	113.0	107.0
H565L80	124.6	112.0	114.0	114.0	120.0	118.0	116.0	112.0	103.0

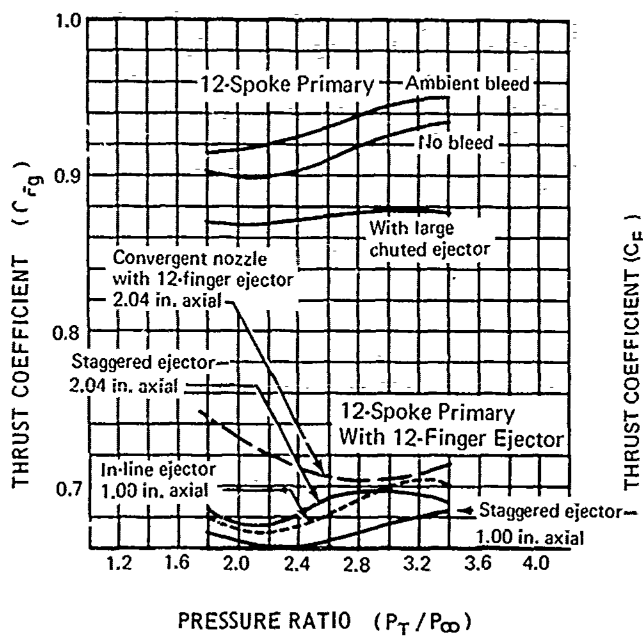
NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

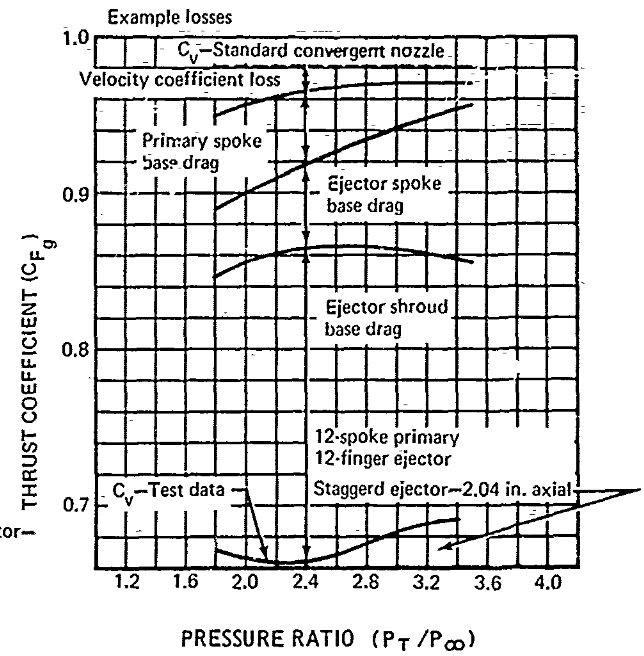
HM-AP-22

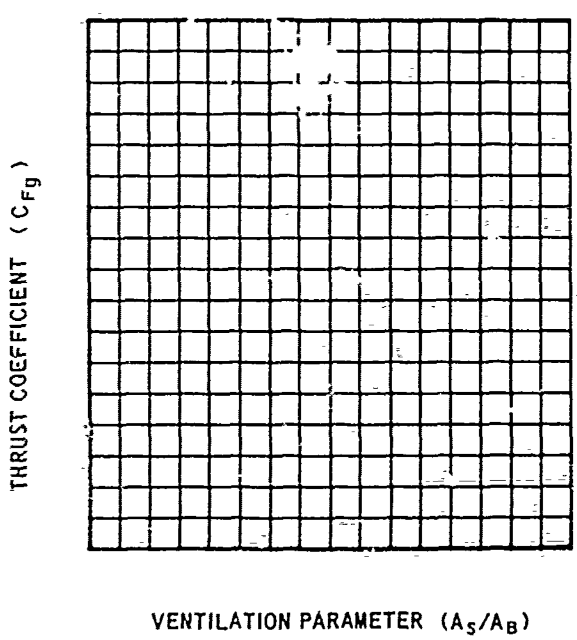


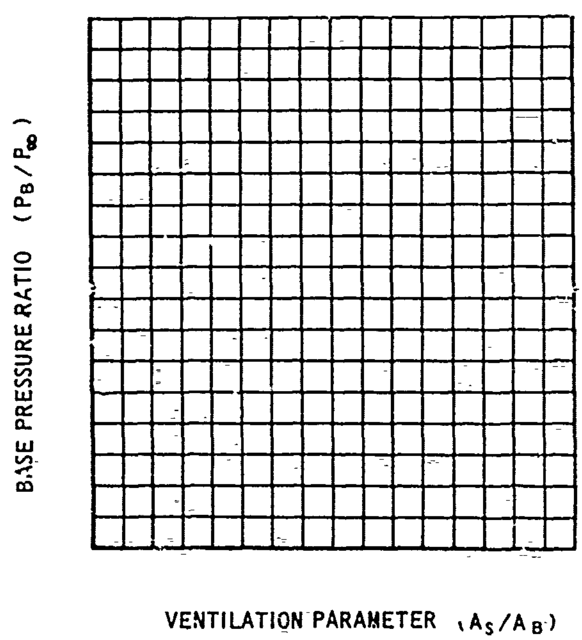
$$C_{F_g} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$

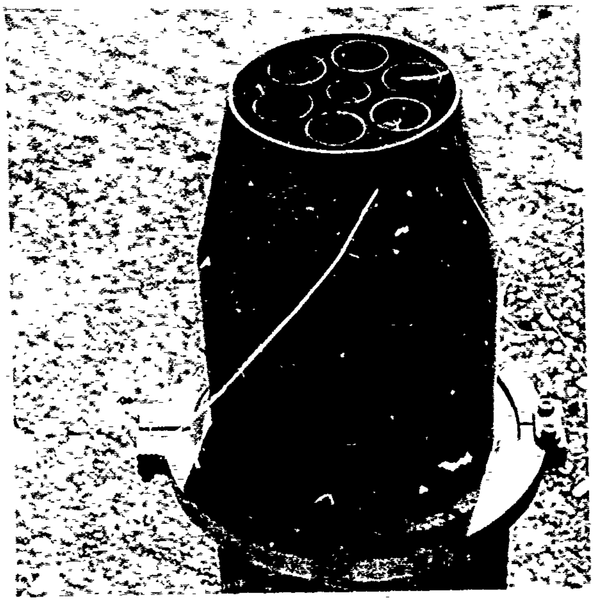








HM-AP-23 NOZZLE
(7 TUBES, INTERNALLY VENTILATED, AR1.8)



Description:

The HM-AP-23 nozzle has a plenum upstream of the nozzle exit plane wherein ambient air is collected from 3 hollow struts and issued through 7 round divergent tubes coplanar with the nozzle exit. The primary flow completely surrounds the 7 tubes.

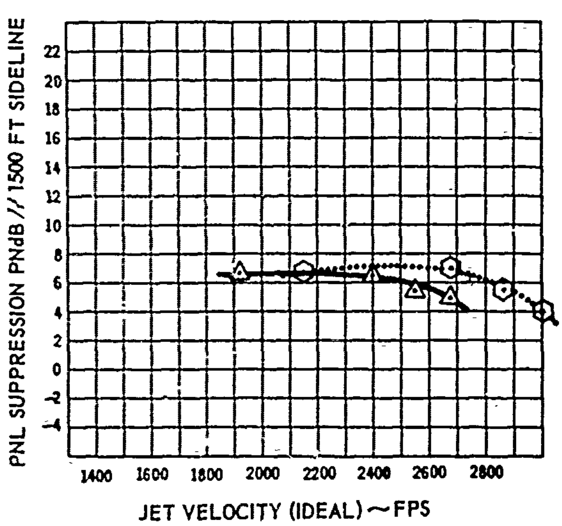
Number of Elements: 7 tubes (for secondary flow)

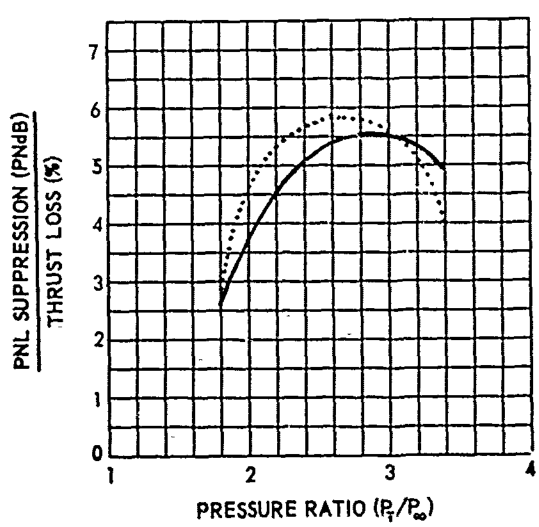
Area Ratio: 1.8

Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees

Material: 321 CRES





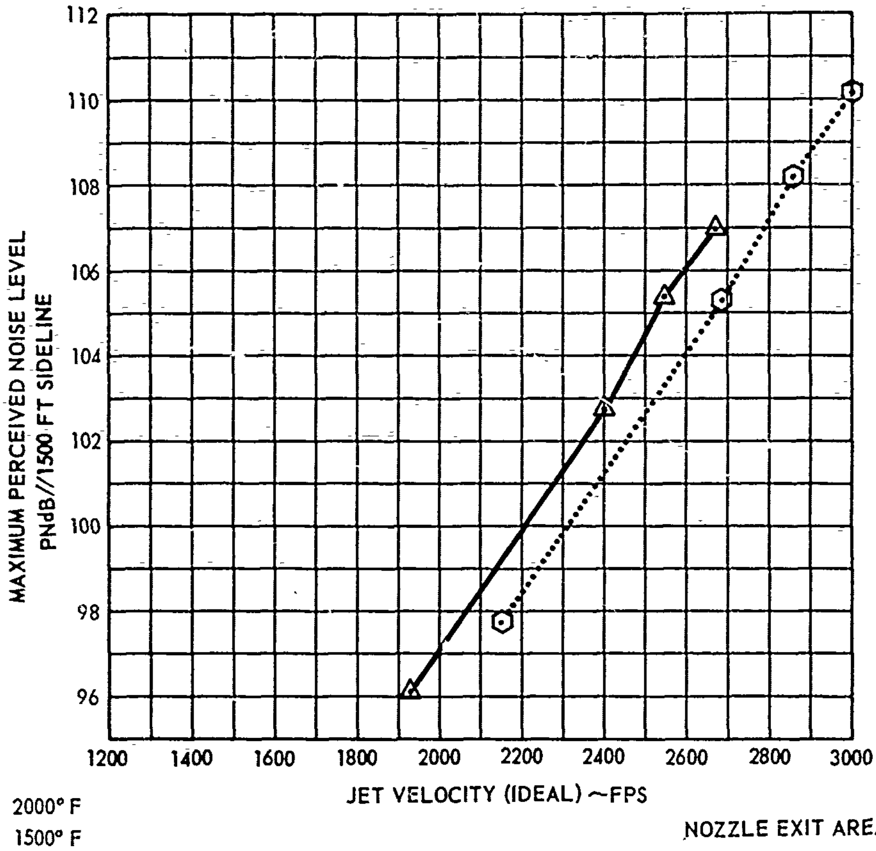
⊙····⊙ 2000° F

△——△ 1500° F

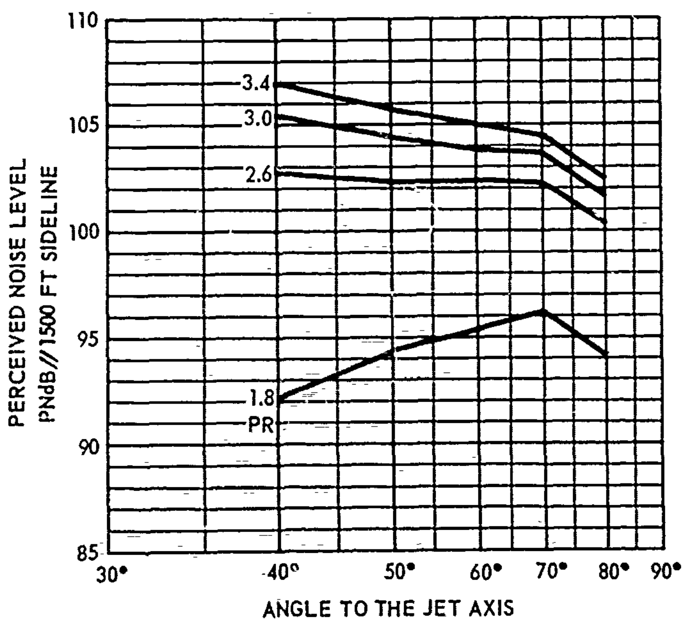
NOZZLE EXIT AREA (A_e): 5.9 FT²

DATA INCLUDES GROUND ~ .FLECTION INTERFERENCE

HM-AP-23 NOZZLE
(7 TUBES, INTERNALLY VENTILATED)
AR 1.8
SCALE FACTOR: 8:1

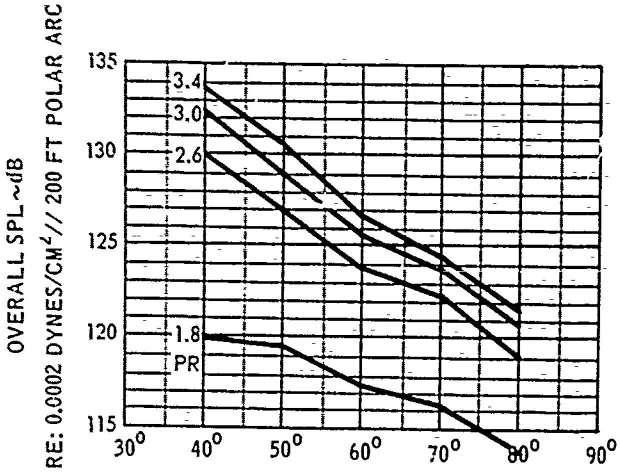


NOZZLE EXIT AREA (A_8): 5.9 FT^2

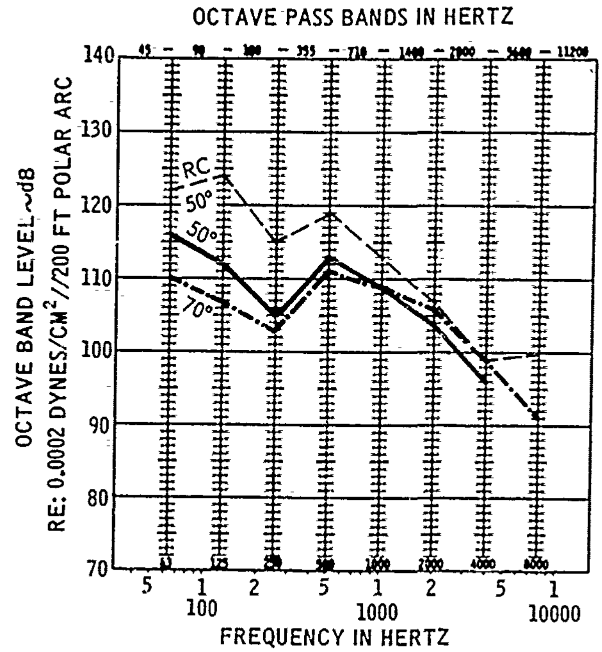


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

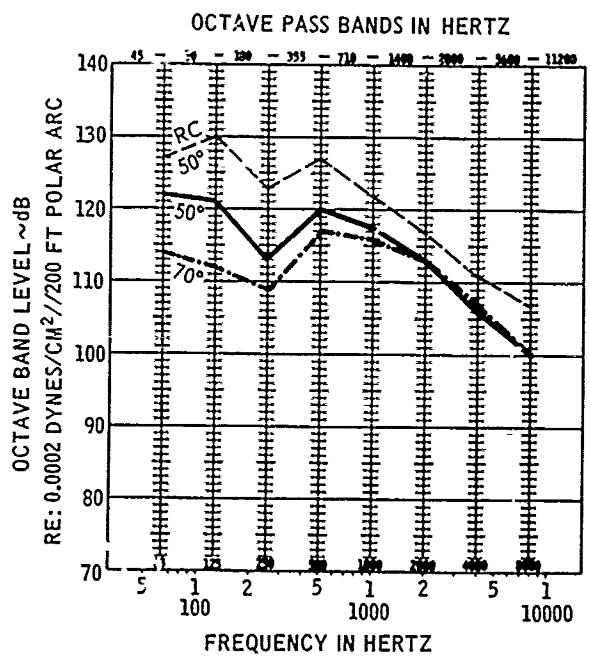


ANGLE TO THE JET AXIS~DEGREES
TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

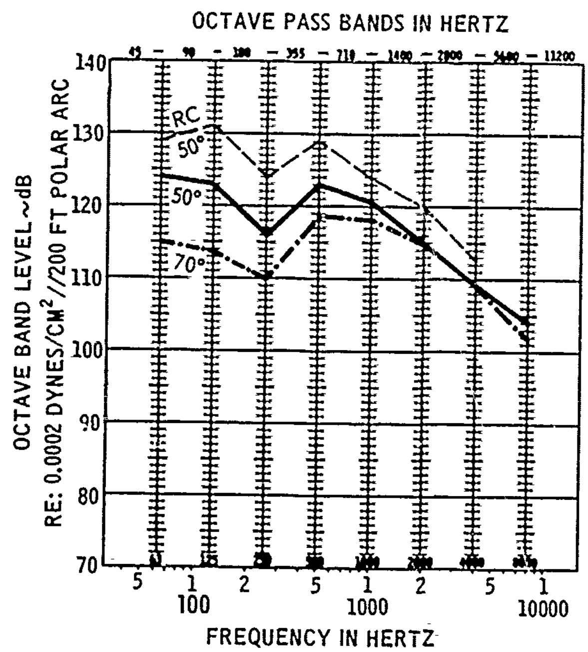


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

HM-AP-23 NOZZLE
(7 TUBES, INTERNALLY VENTILATED)
AR 1.8
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2402 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-23 NOZZLE

(7 Tubes, Internally Ventilated, AR = 1.8)

Remarks:

Another nozzle (HM-AP-56) with 37 tubes, internally ventilated, was tested. Internally ventilated tube nozzles potentially offer the advantage of increasing primary flow mixing with tube elements and low area ratios. See Reference D12.

HM-AP-23

Test Facility: Annex D (Cell #1)

Date:

T_{amb}:

R. H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H992	1.8	1500°F	1923 fps	HM-AP-23
H993	2.6	"	2402	"
H994	3.0	"	2555	"
H995	3.4	"	2678	"
H996	1.8	2000°F	2154	"
H997	2.6	"	2691	"
H998	3.0	"	2862	"
H999	3.4	"	3000	"
H982	1.8	1500°F	1923 fps	4.1 Inch Round Convergent Nozzle
H983	2.6	"	2402	"
H984	3.0	"	2555	"
H985	3.4	"	2678	"
H1005	1.8	2000°F	2154	"
H1006	2.6	"	2691	"
H1007	3.0	"	2862	"
H1008	3.4	"	3000	"

Measured acoustic data for these runs are recorded in Reference D2.

NOZZLE TEST DATA
HM–AP–23

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H992L40	119.8	115.5	114.0	105.0	113.0	110.0	104.0	95.0	0.0
H992L50	119.5	116.0	112.0	105.0	113.0	109.0	104.0	96.0	0.0
H992L60	117.4	112.5	108.0	106.0	112.0	109.0	104.0	97.0	0.0
H992L70	116.3	110.0	107.0	103.0	111.0	109.0	106.0	99.0	91.0
H992L80	113.4	107.0	105.0	101.0	108.5	105.0	103.0	96.0	0.0
H993L40	130.0	125.0	126.0	117.0	121.5	118.5	113.0	107.0	106.0
H993L50	126.9	122.0	121.0	113.0	120.0	117.5	113.0	106.0	100.0
H993L60	123.9	117.5	115.0	112.0	119.0	116.0	112.5	105.0	98.0
H993L70	122.2	114.0	112.0	109.0	117.0	116.0	113.0	107.0	100.0
H993L80	119.1	111.0	110.0	107.0	114.0	112.0	110.0	104.0	95.0
H994L40	132.4	126.5	128.0	121.0	125.5	121.0	117.0	110.0	108.0
H994L50	129.0	124.0	123.0	116.0	122.0	120.5	115.0	109.0	104.0
H994L60	125.5	119.0	116.0	114.0	120.5	118.0	114.0	107.8	100.0
H994L70	123.8	115.0	113.5	110.0	118.5	118.0	115.0	109.0	102.0
H994L80	120.6	112.0	114.0	108.0	115.0	114.0	113.0	106.0	98.0
H995L40	133.9	128.0	130.0	123.0	126.0	122.0	118.0	112.0	110.0
H995L50	130.5	125.0	125.0	117.0	123.5	121.5	117.0	110.0	105.0
H995L60	126.6	120.0	118.0	115.0	121.5	119.0	115.5	109.0	102.0
H995L70	124.4	116.0	115.0	111.0	119.0	118.0	116.0	110.0	103.0
H995L80	121.5	112.0	112.0	109.0	116.0	115.0	114.0	108.0	0.0
H996L40	123.2	119.0	119.0	108.0	114.0	111.0	106.5	98.0	97.0
H996L50	121.3	117.0	115.0	107.0	115.0	111.0	106.0	98.0	0.0
H996L60	119.0	113.0	110.0	108.0	114.0	111.0	106.0	99.0	0.0
H996L70	117.6	109.0	108.0	105.0	113.0	111.0	108.0	100.5	93.0
H996L80	115.4	107.0	106.0	105.0	111.0	108.0	105.0	98.0	0.0
H997L40	131.9	126.0	128.0	121.0	124.0	120.0	116.0	109.0	107.0
H997L50	129.7	124.0	125.0	117.0	122.5	120.0	115.0	109.0	104.0
H997L60	126.3	119.0	118.0	114.5	121.5	119.0	115.0	108.0	101.0
H997L70	124.3	114.5	114.0	111.0	120.0	118.0	115.0	108.5	101.5
H997L80	121.1	111.0	111.5	109.0	117.0	114.0	112.0	105.0	97.0
H998L40	134.2	128.0	130.5	123.5	126.0	122.0	118.0	111.0	110.0
H998L50	132.5	126.0	128.0	121.0	126.0	122.0	118.0	112.0	107.0
H998L60	128.7	121.0	121.0	117.0	124.0	121.0	117.0	111.0	105.0
H998L70	126.1	117.0	110.0	114.0	122.0	120.0	117.0	110.5	104.0
H998L80	123.0	113.0	113.0	111.0	118.5	116.5	114.0	108.0	0.0
H999L40	135.2	129.0	131.5	124.5	127.0	123.0	119.0	112.0	111.0
H999L50	134.4	127.5	130.0	123.0	128.0	124.0	120.0	114.0	109.0
H999L60	130.0	122.0	122.0	119.0	125.0	123.0	118.0	112.0	107.0
H999L70	127.8	118.0	117.5	115.0	123.0	122.0	118.0	113.0	107.0
H999L80	124.8	114.0	115.0	113.0	120.0	118.5	116.0	110.0	102.0
H982L40	127.8	122.0	125.0	117.0	118.0	111.0	105.0	96.0	103.0
H982L50	127.4	122.0	124.0	115.0	119.0	113.0	107.0	99.0	100.0
H982L60	123.5	118.0	119.0	110.0	117.0	112.0	106.0	97.5	98.0
H982L70	120.2	113.5	114.0	109.0	115.0	111.0	107.0	98.0	95.0
H982L80	116.7	109.0	109.0	106.0	112.0	109.0	104.0	95.0	89.0
H983L40	133.5	127.0	130.0	123.0	125.5	120.5	116.0	108.0	0.0
H983L50	134.1	128.0	130.0	123.0	127.0	122.0	118.0	111.0	107.0
H983L60	131.3	124.0	126.0	118.5	126.0	122.0	117.0	110.0	105.0
H983L70	127.7	119.0	121.0	116.0	123.0	119.0	117.0	110.0	105.0
H983L80	124.6	114.0	115.0	112.0	119.5	119.0	116.0	108.0	101.0
H984L40	134.8	129.0	131.0	124.0	127.0	122.0	118.0	110.0	0.0
H984L50	135.4	129.0	131.0	124.0	129.0	124.0	120.0	113.0	0.0
H984L60	132.6	126.0	127.0	120.0	127.0	123.0	119.0	115.0	107.0
H984L70	129.6	121.0	123.0	119.0	124.0	[illegible]	119.0	113.0	108.0
H984L80	127.7	116.0	116.0	115.0	122.0	122.0	119.5	118.0	111.0
H985L40	135.8	130.0	132.0	125.0	128.0	123.0	119.0	111.0	0.0
H985L50	136.8	131.0	132.0	126.0	130.0	125.0	122.0	115.0	0.0
H985L60	133.8	127.5	128.0	122.0	128.0	124.0	121.0	114.0	0.0
H985L70	130.9	123.0	124.0	120.0	125.0	123.0	121.0	114.0	0.0
H985L80	128.4	117.0	117.0	116.0	123.0	124.0	119.0	112.0	0.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

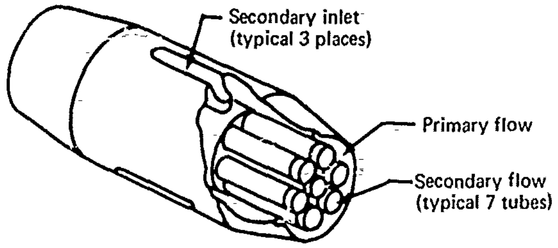
OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-23

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H1005L40	128.0	121.0	125.0	118.0	120.0	114.0	108.0	100.0	-0.0
H1005L50	128.1	121.0	124.0	117.0	122.0	116.0	110.5	102.0	-0.0
H1005L60	125.8	117.5	120.0	116.0	121.0	116.0	111.0	102.0	97.0
H1005L70	122.4	113.0	115.5	110.0	118.0	115.0	111.0	102.0	-0.0
H1005L80	119.0	109.0	110.0	108.0	115.0	112.0	108.0	99.5	92.0
H1006L40	132.8	126.5	129.0	122.0	125.0	121.0	117.0	109.0	108.0
H1006L50	134.0	127.0	129.5	123.0	128.0	123.0	119.0	113.0	108.0
H1006L60	133.2	123.5	126.5	123.5	129.0	124.0	121.0	114.0	108.0
H1006L70	130.2	119.0	122.5	118.0	126.0	123.0	120.0	113.0	108.0
H1006L80	126.7	114.0	116.0	114.5	123.0	120.0	118.0	111.0	[illegible]
H1007L40	133.9	128.0	130.0	123.0	126.0	122.0	118.0	110.0	109.0
H1007L50	135.2	128.0	131.0	124.0	129.0	124.0	121.0	114.0	109.0
H1007L60	134.8	125.0	128.0	125.0	130.5	126.0	122.0	116.0	111.0
H1007L70	131.5	121.0	124.0	120.0	127.0	124.5	121.0	115.0	110.0
H1007L80	128.3	115.5	118.0	116.0	124.0	122.0	120.0	113.5	105.0
H1008L40	135.4	129.5	132.0	125.0	126.0	123.0	119.0	112.0	110.0
H1008L50	136.4	129.5	132.0	126.0	130.0	125.0	122.0	115.0	111.0
H1008L60	135.6	126.0	129.0	126.0	131.0	127.0	123.0	117.0	112.0
H1008L70	132.2	122.0	125.0	120.5	127.5	125.0	122.0	116.0	111.0
H1008L80	129.2	116.0	119.0	117.0	125.0	123.0	121.0	114.0	107.0

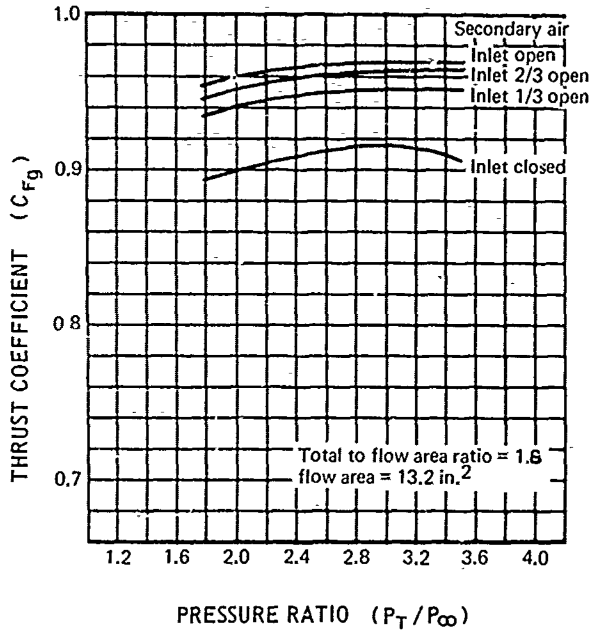
NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

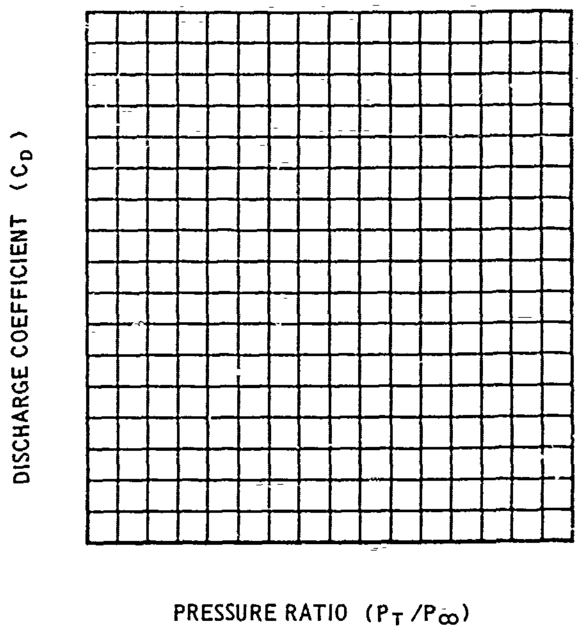
HM-AP-23

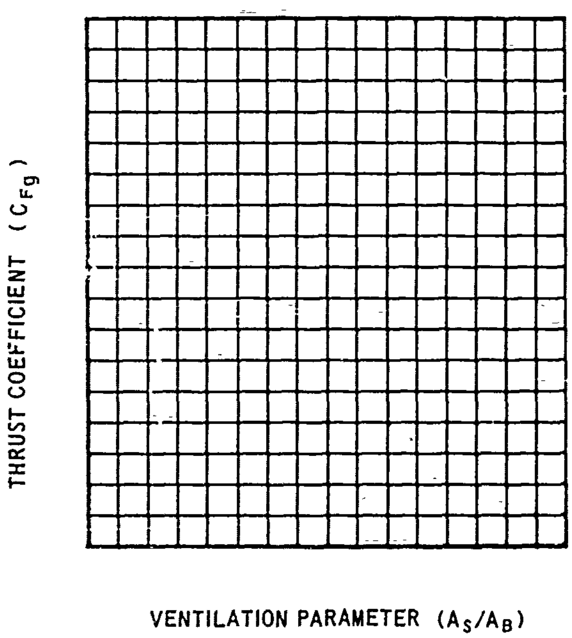


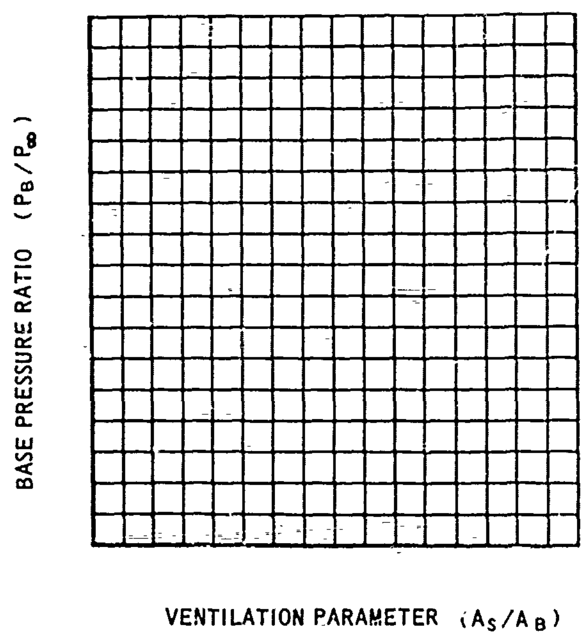
$$C_{Fg} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$

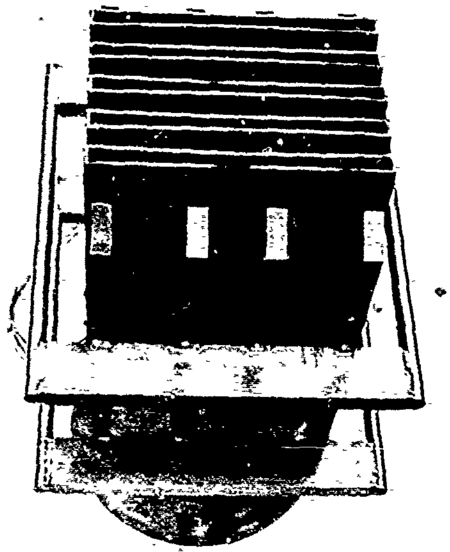








HM-AP-24 NOZZLE
5 PARALLEL SLOTS, HORIZONTAL
AR 3.0



Description:

Number of Elements: 5 parallel convergent slots

Area Ratio: 3.0

Flow Area: 13.2 square inches

Nozzle Cant Angle: 0 degrees

Element Length: 10.8 inches

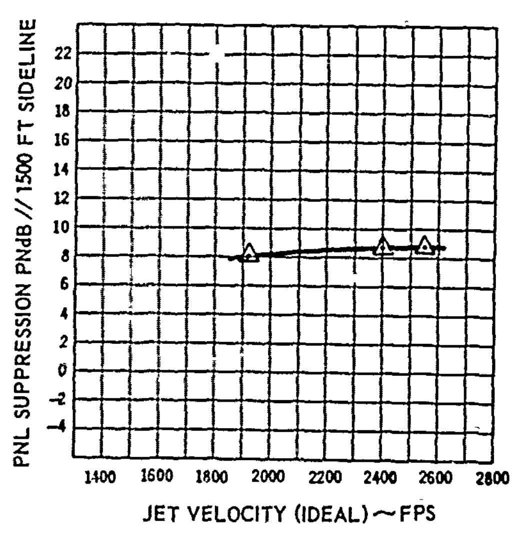
Slot Dimension: 7.2 inches x 0.367 inches

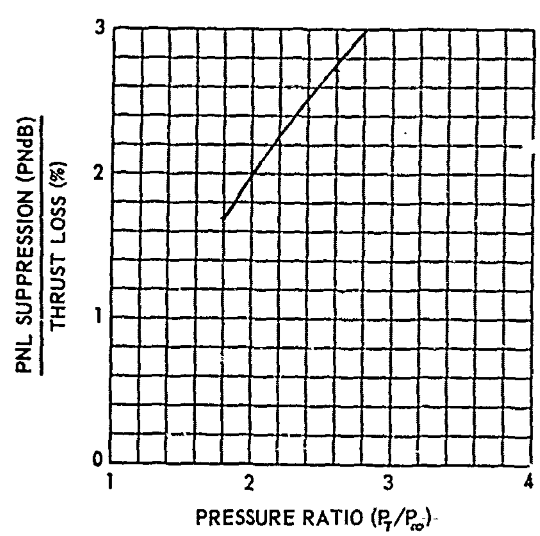
Slot Aspect Ratio: 7.2/0.367 = 19.5

Nozzle Array Dimensions: 7.2 inches x 4.95 inches

Distance Between Slots: 0.734 in.

Material: 321 CRES

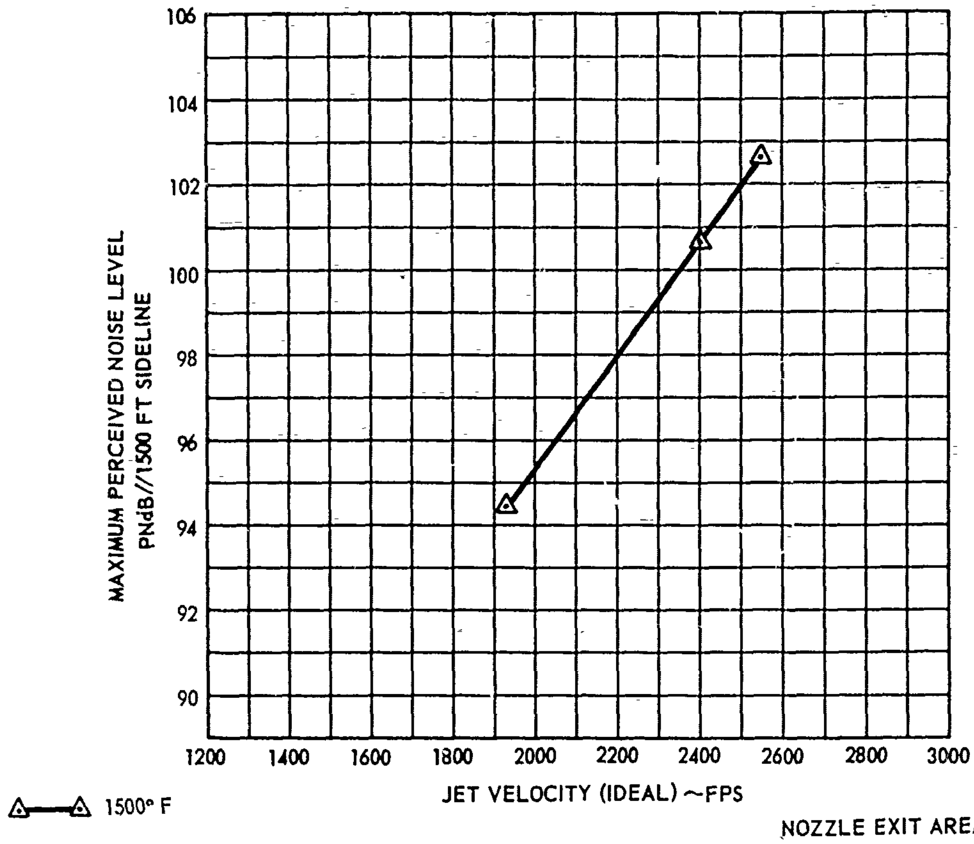




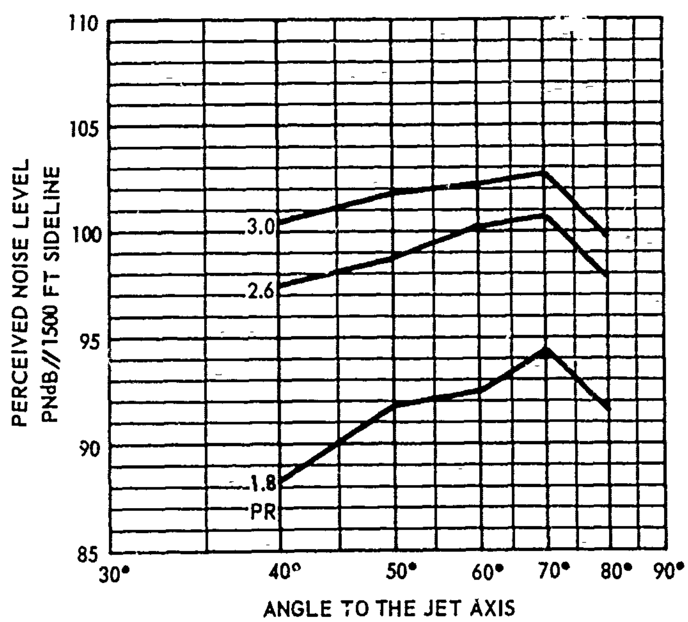
NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-24 NOZZLE
(5 PARALLEL SLOTS, HORIZONTAL)
AR 3.0
SCALE FACTOR: 8:1

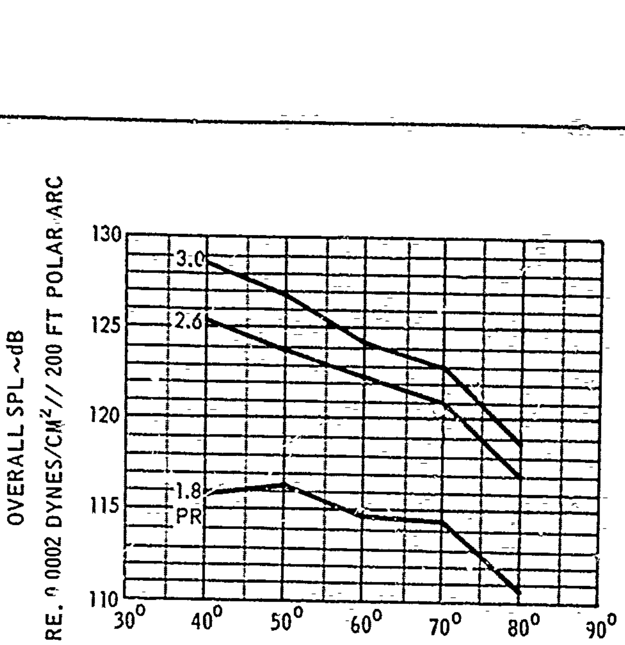


NOZZLE EXIT AREA (A_8): 5.9 FT^2

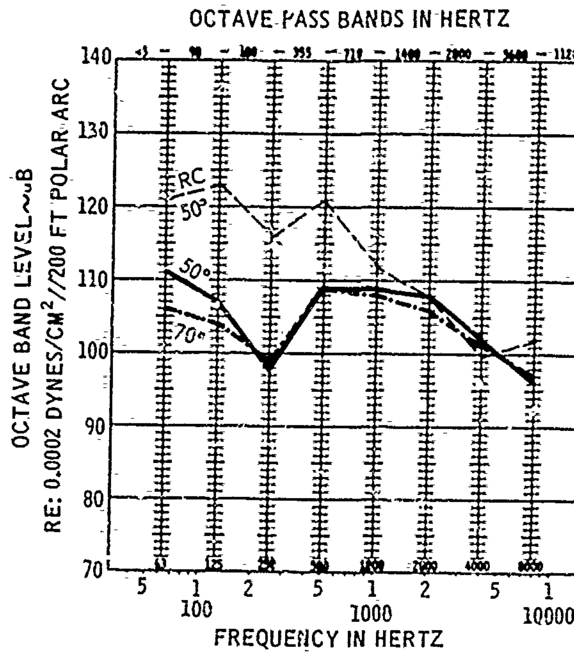


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

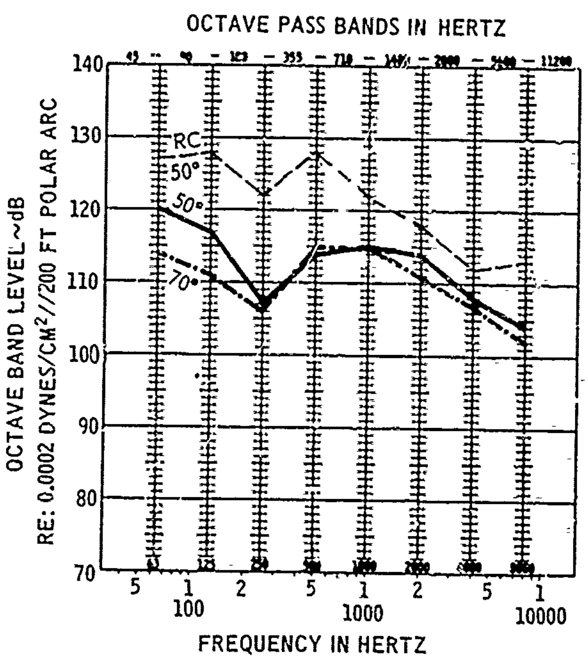


ANGLE TO THE JET AXIS~DEGREES
TOTAL TEMPERATURE (T_8) : 1500°F
NOZZLE EXIT AREA (A_8): 5.9 FT²

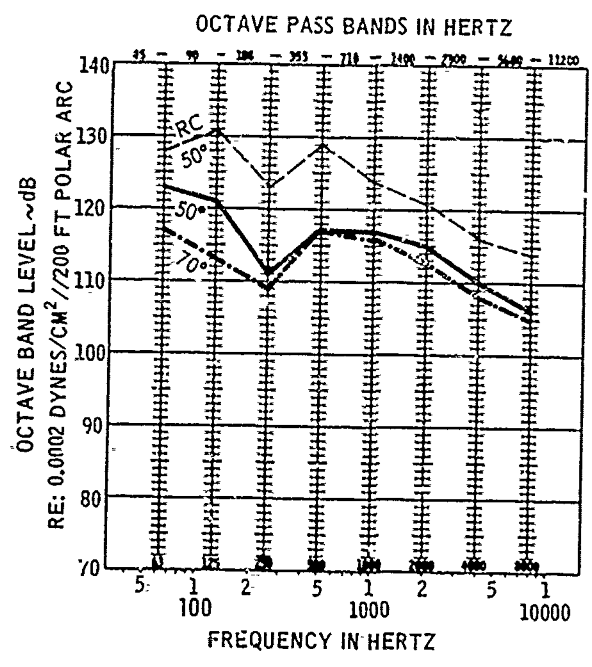


HM-AP-24 NOZZLE
(5 PARALLEL SLOTS, HORIZONTAL)
AR 3.0
SCALE FACTOR: 8:1

PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500°F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



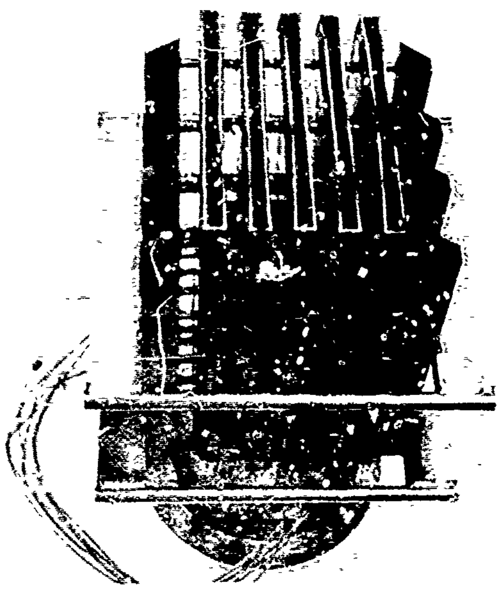
PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1500°F
JET VELOCITY (IDEAL): 2402 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

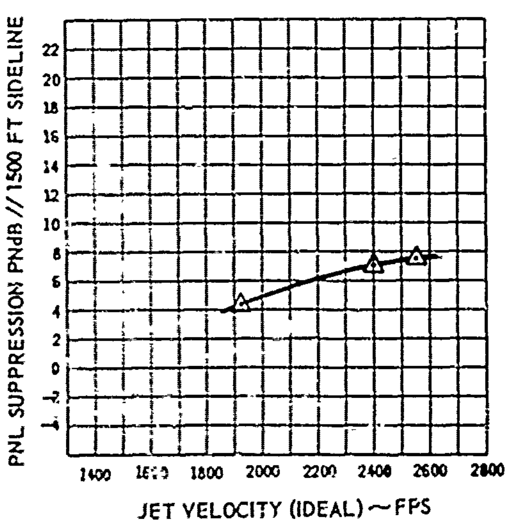


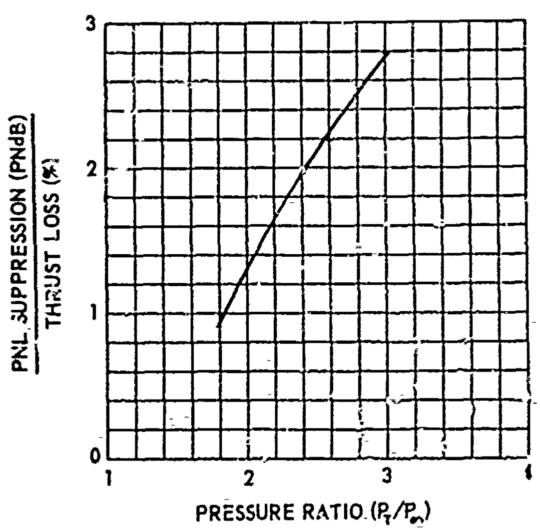
PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500°F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-24 NOZZLE
(5 PARALLEL SLOTS, VERTICAL)





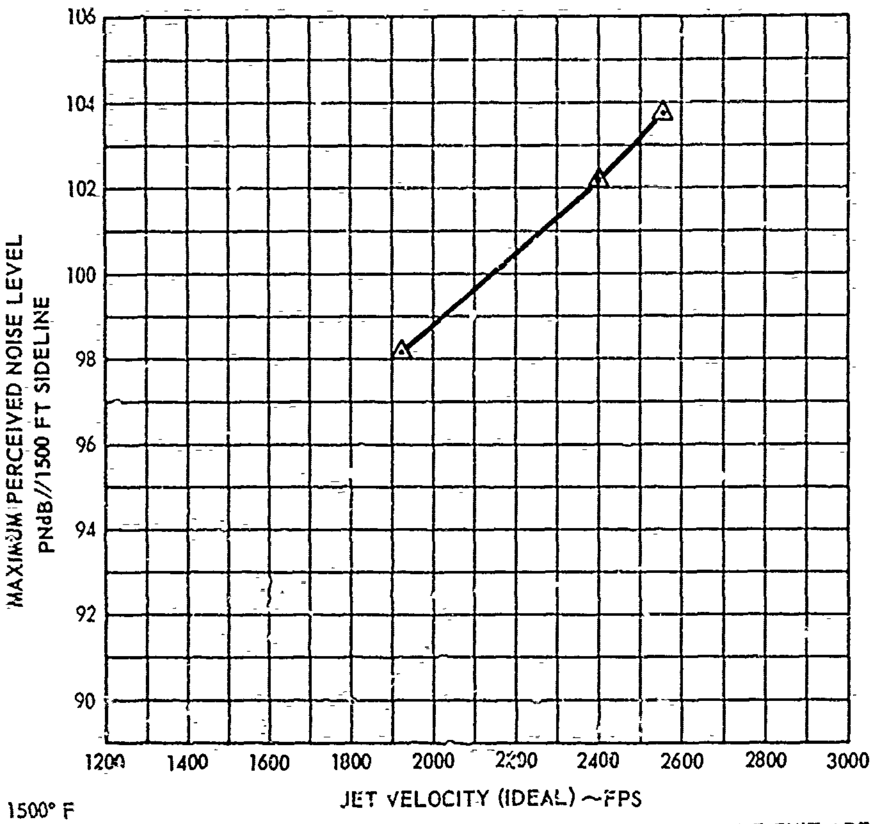


△—△ 1500° F

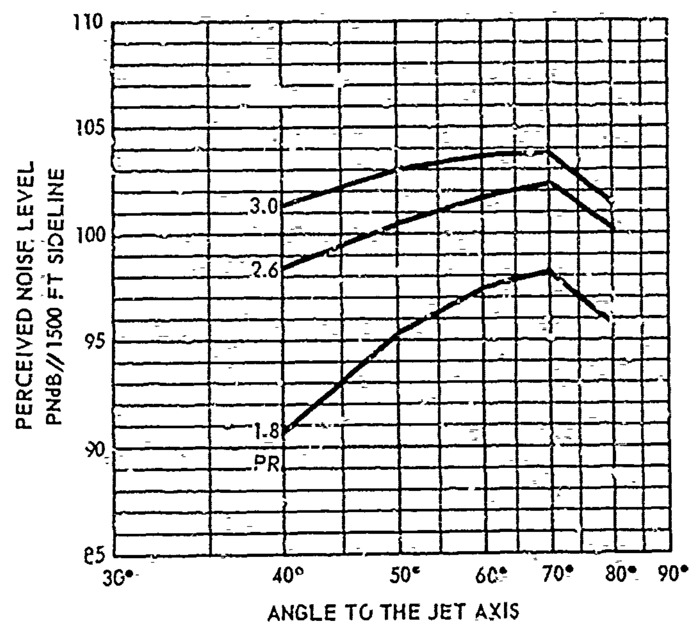
NOZZLE EXIT AREA (A_e): 5.9 FT^2

NOTE: INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-24 NOZZLE
(5 PARALLEL SLOTS, VERTICAL)
AR 3.J
SCALE FACTOR 8:1



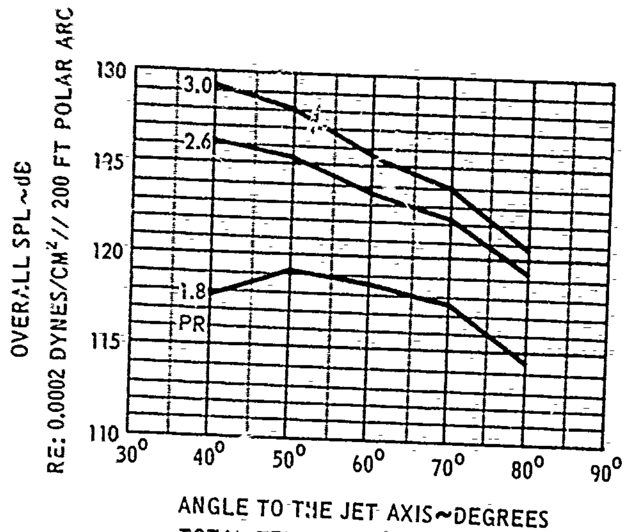
NOZZLE EXIT AREA (A_8): 5.9 FT^2



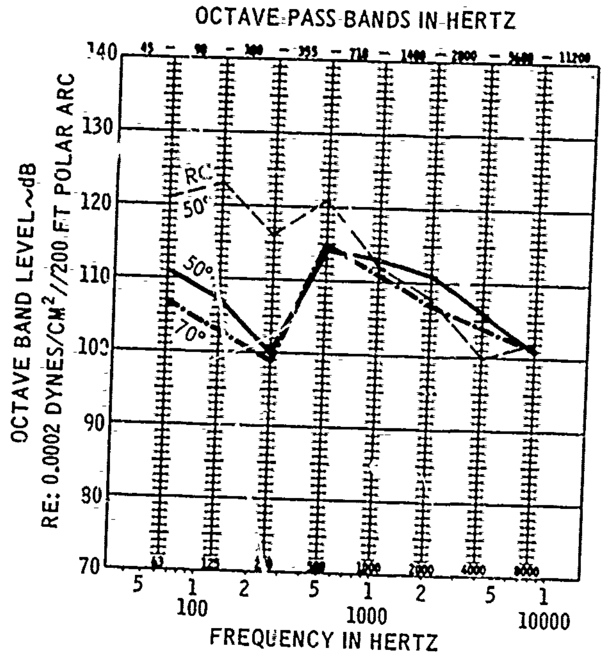
TOTAL TEMPERATURE (T_8): 1500° F

NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

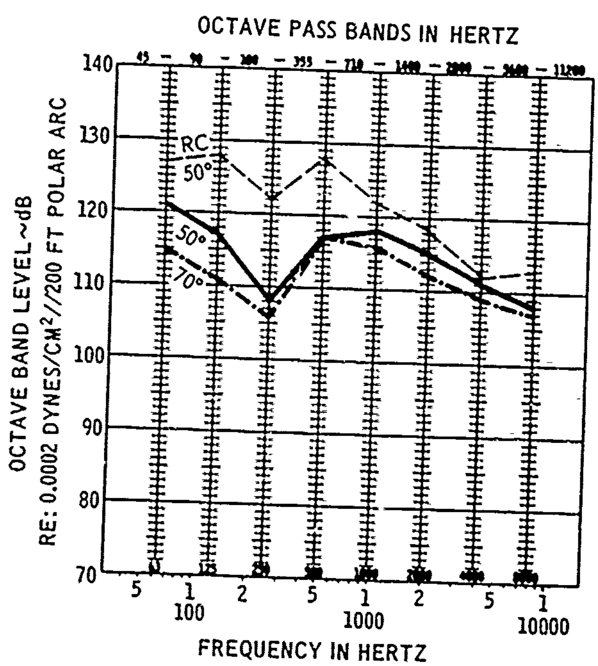


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

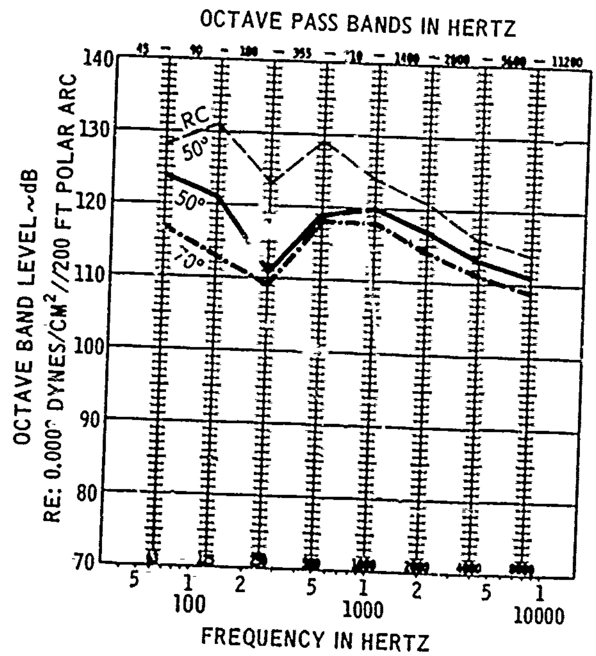


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

HM-AP-24 NOZZLE
(5 PARALLEL SLOTS, VERTICAL)
AR 3.0
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2402 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-24 NOZZLE

(5 Parallel Slots, AR = 3.0)

Remarks

The HM-AP-24 nozzle was intended to be one of a series of rectangular slot nozzles to determine the noise characteristics of this type of array. The HM-AP-25 nozzle array was similar to the HM-AP-24 since the flow parameters at the exit plane were identical. The HM-AP-24 nozzle had convergent slot sides whereas the HM-AP-25 nozzle had convergent slot ends. The HM-AP-25 nozzle was destroyed during testing. The HM-AP-26 nozzle was designed for an area ratio of 2.0 and the HM-AP-27 nozzle was designed for an area ratio of 4.0. The HM-AP-26 and HM-AP-27 nozzles were never constructed.

HM-AP-24 nozzle element length was adjusted to 10.8, 7.2, 3.6 and 0 inches by installing ventilation blockers of the appropriate dimensions. Noise suppression characteristics were substantially not affected by element length at pressure ratios of 2.6 and 3.0. Maximum noise suppression was noted when the microphones were oriented in respect to the nozzle so that the slots are viewed on-end (nozzle slots horizontal). There was 2 to 3.5 PNdB less suppression evident when the slots are viewed on the long side (nozzle slots vertical). See Reference D13.

HM-AP-24

Facility; Annex D (Cell #1)
Nozzle and Microphone Height are 18 Inches

Date:

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_J(Ideal)	Nozzle
H 1163	1.8	1500°F	1923 fps	HM-AP-24 [1]
H 1164	2.6	"	2402	"
H 1165	3.0	"	2555	"
H 1172	1.8	1500°F	1923	HM-AP-24 [2]
H 1173	2.6	"	2402	"
H11174	3.0	"	2555	"
H 1166	1.8	1500°F	1923	4.1-Inch Round Convergent Nozzle
H 1167	2.6	"	2402	"
H 1168	3.0	"	2555	"

[1] Nozzle slots are horizontal

[2] Nozzle slots are vertical

Note: Measured acoustic data is recorded in Reference D2.

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

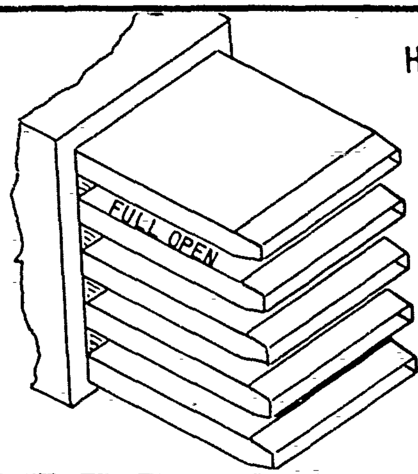
HM-AP-24

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H1163L40	115.9	112.0	107.0	98.0	108.0	108.0	106.0	99.0	95.0
H1163L50	116.3	111.0	107.0	98.0	109.0	109.0	108.0	102.0	96.0
H1163L60	114.6	109.0	105.0	100.0	109.0	108.0	103.0	96.0	0.0
H1163L70	114.4	106.0	104.0	99.0	109.0	108.0	106.0	101.0	97.0
H1163L80	110.7	103.0	101.0	96.0	105.0	104.0	102.0	99.0	90.0
H1164L40	125.3	123.0	118.0	107.0	113.0	114.0	113.0	106.0	103.0
H1164L50	123.9	120.0	117.0	107.0	114.0	115.0	114.0	108.0	104.0
H1164L60	122.3	117.0	113.0	107.0	115.0	115.0	113.0	109.0	103.0
H1164L70	121.0	114.0	111.0	106.0	115.0	115.0	111.0	107.0	103.0
H1164L80	117.0	110.0	107.0	103.0	111.0	110.0	108.0	105.0	97.0
H1165L40	128.6	126.0	123.0	111.0	116.0	116.0	114.0	107.0	105.0
H1165L50	126.8	123.0	121.0	111.0	117.0	117.0	115.0	110.0	106.0
H1165L60	124.2	119.0	115.0	110.0	117.0	117.0	115.0	110.0	104.0
H1165L70	123.0	117.0	113.0	109.0	117.0	116.0	113.0	108.0	103.0
H1165L80	118.9	112.0	109.0	105.0	113.0	112.0	110.0	106.0	99.0
H1172L40	117.9	112.0	107.0	99.0	111.0	112.0	109.0	104.0	100.0
H1172L50	119.1	111.0	107.0	100.0	114.0	113.0	111.0	106.0	101.0
H1172L60	118.6	109.0	105.0	101.0	115.0	112.0	109.0	105.0	99.0
H1172L70	117.8	107.0	103.0	99.0	115.0	111.0	107.0	104.0	101.0
H1172L80	114.5	104.0	100.0	97.0	112.0	107.0	103.0	101.0	95.0
H1173L40	126.2	123.0	120.0	109.0	115.0	117.0	113.0	109.0	106.0
H1173L50	125.4	121.0	117.1	108.0	117.0	118.0	115.0	111.0	108.0
H1173L60	123.7	118.0	113.0	108.0	117.0	117.0	115.0	110.0	106.0
H1173L70	122.2	115.0	111.0	106.0	117.0	116.0	112.0	109.0	107.0
H1173L80	119.3	111.0	107.0	103.0	114.0	114.0	109.0	107.0	102.0
H1174L40	129.2	126.0	124.0	112.0	117.0	118.0	115.0	110.0	108.0
H1174L50	128.1	124.0	121.0	111.0	119.0	120.0	117.0	113.0	111.0
H1174L60	125.7	120.0	116.0	111.0	119.0	119.0	116.0	112.0	108.0
H1174L70	124.0	117.0	113.0	109.0	118.0	118.0	114.0	111.0	109.0
H1174L80	120.8	113.0	109.0	106.0	114.0	116.0	111.0	109.0	103.0
H1166L40	127.1	121.0	123.0	116.0	121.0	112.0	108.0	100.0	102.0
H1166L50	127.2	121.0	123.0	115.0	121.0	114.0	110.0	103.0	102.0
H1166L60	122.8	119.0	116.0	111.0	116.0	111.0	108.0	101.0	97.0
H1166L70	120.2	113.0	113.0	108.0	116.0	111.0	107.0	101.0	96.0
H1166L80	119.6	108.0	107.0	105.0	111.0	100.0	104.0	98.0	91.0
H1167L40	132.3	127.0	128.0	121.0	125.0	118.0	116.0	109.0	108.0
H1167L50	133.1	127.0	128.0	122.0	128.0	122.0	118.0	112.0	113.0
H1167L60	130.8	123.0	124.0	121.0	126.0	121.0	118.0	113.0	108.0
H1167L70	127.0	118.0	119.0	115.0	123.0	119.0	116.0	110.0	106.0
H1167L80	122.5	113.0	113.0	111.0	118.0	116.0	112.0	107.0	100.0
H1168L40	133.7	128.0	130.0	122.0	126.0	119.0	116.0	110.0	110.0
H1168L50	135.2	128.0	131.0	123.0	129.0	124.0	121.0	116.0	114.0
H1168L60	132.8	124.0	126.0	123.0	128.0	124.0	121.0	115.0	111.0
H1168L70	128.8	120.0	121.0	118.0	124.0	121.0	118.0	113.0	109.0
H1168L80	124.7	114.0	114.0	113.0	120.0	119.0	115.0	110.0	103.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

AC 1540D

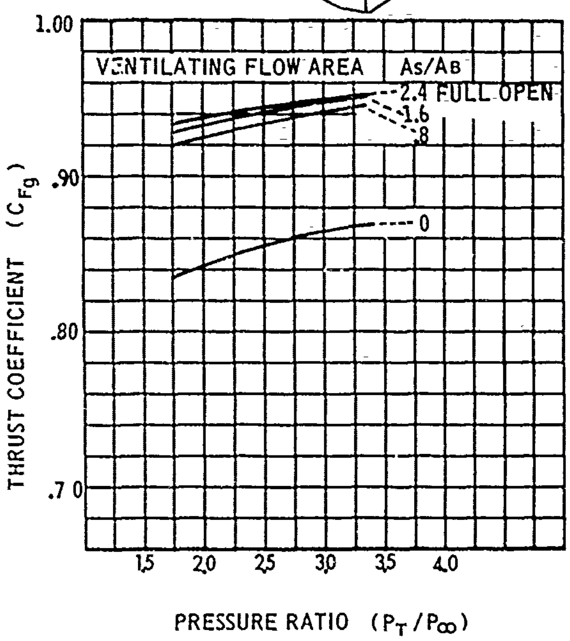
HM-AP-24

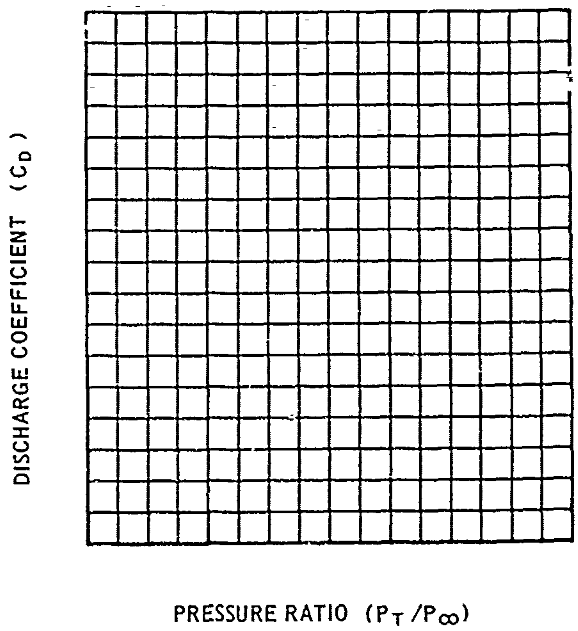


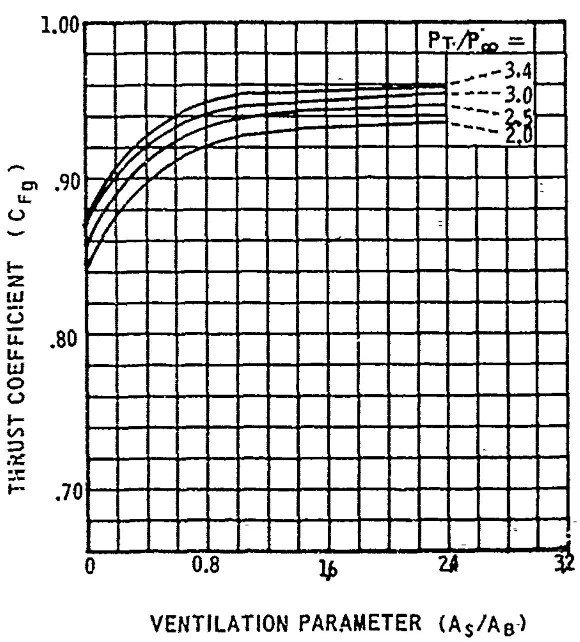
RECTANGULAR BLOCKERS SLOT SPACING RATIO 2:1

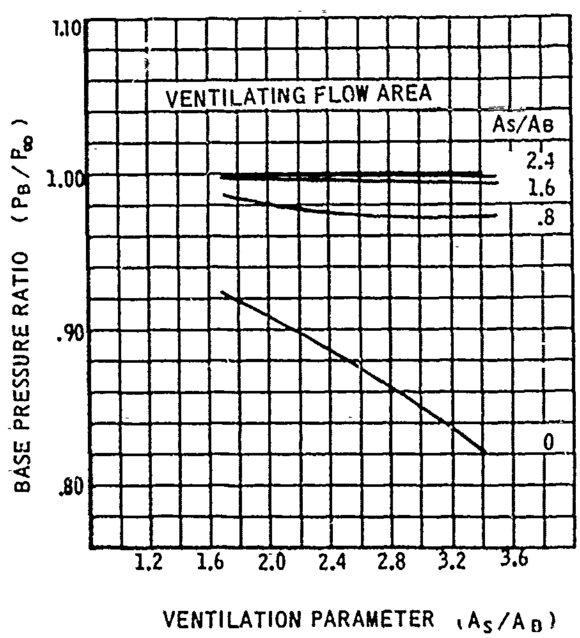
$$C_{Fg} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



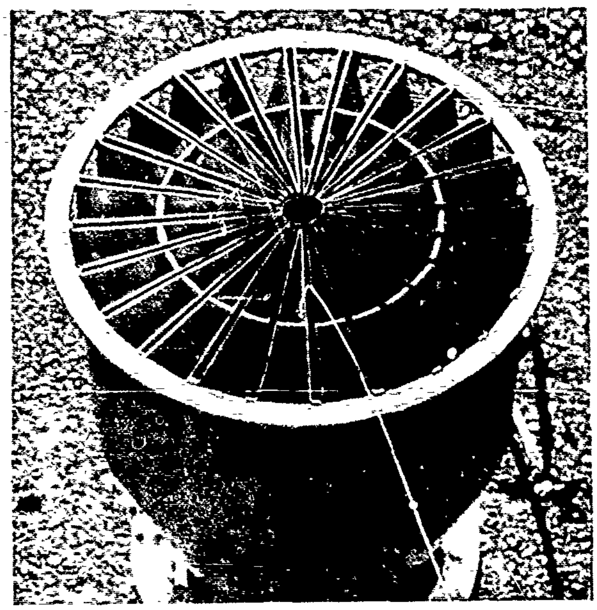






HM-AP-28 NOZZLE

24 SPOKES, AR 6.0



Description

Number of Elements: 24 spokes

Area Ratio: 6.0

Spoke Penetration: 92.5%

Flow Area: 13.2 square inches

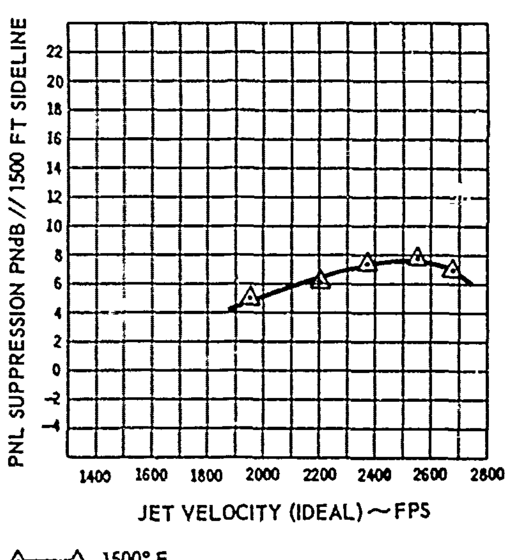
Exit Cant Angle: 0 degrees

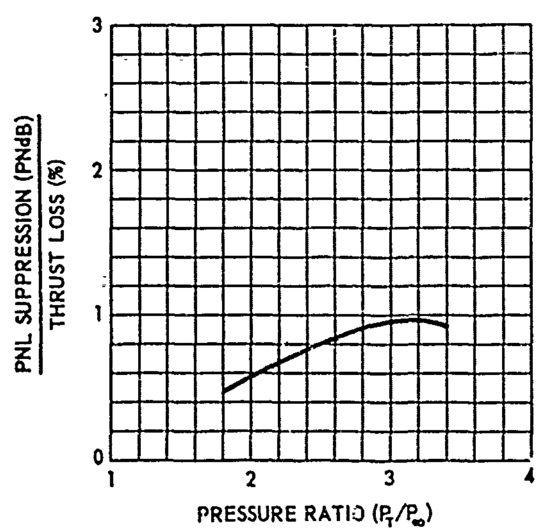
Ventilation Gutter Cant Angle: 30 degrees

Nozzle Diameter: 10 inches

Spoke Width: Varied from 0.15" to 0.1"

Material: 321 CRES

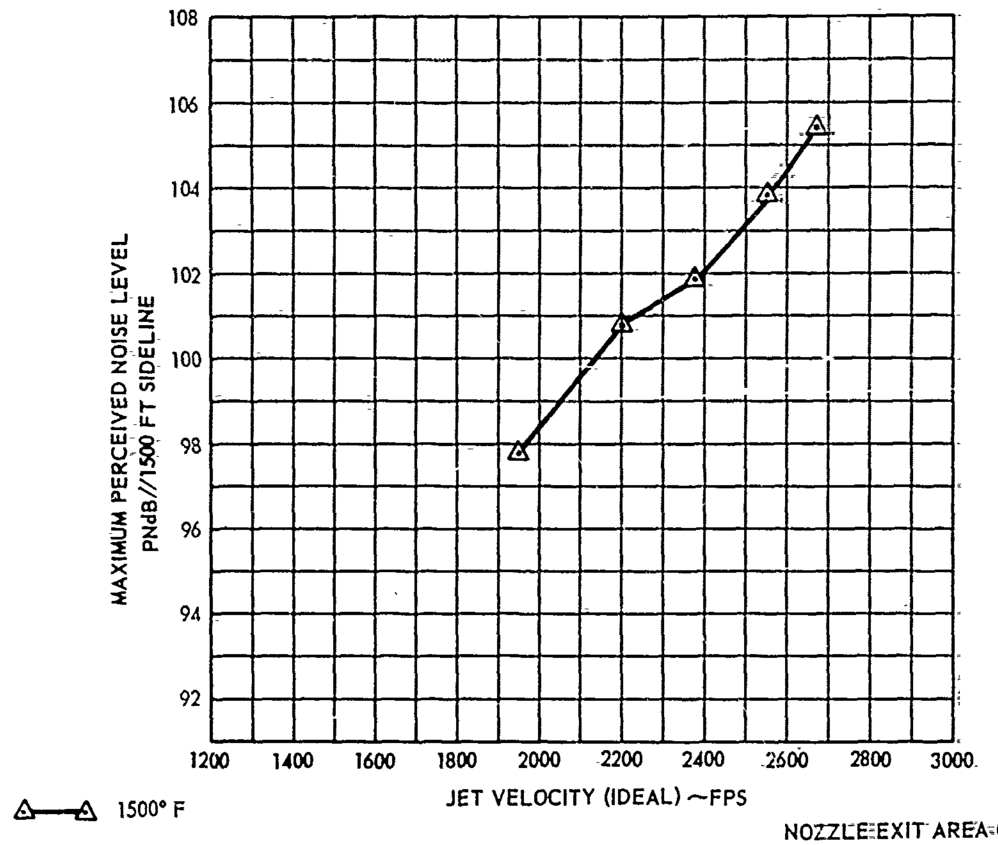




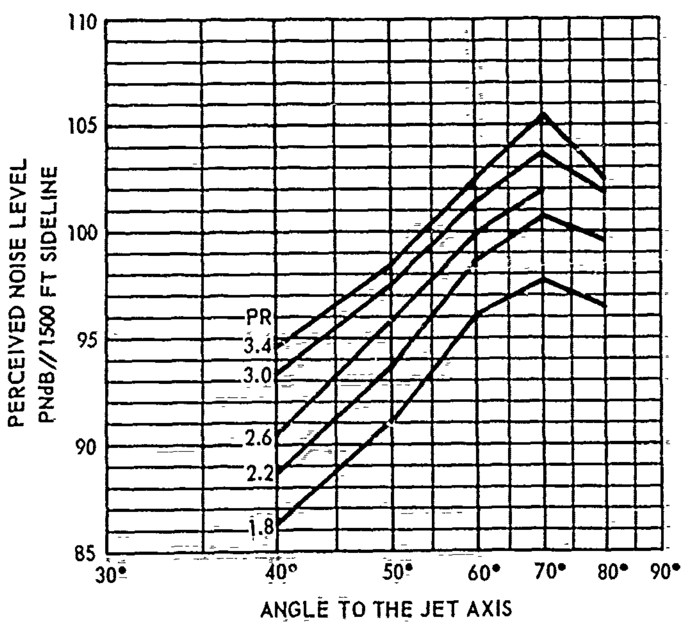
NOZZLE EXIT AREA (A_e): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-28 NOZZLE
(24 SPOKES)
AR 6.0
SCALE FACTOR: 8:1

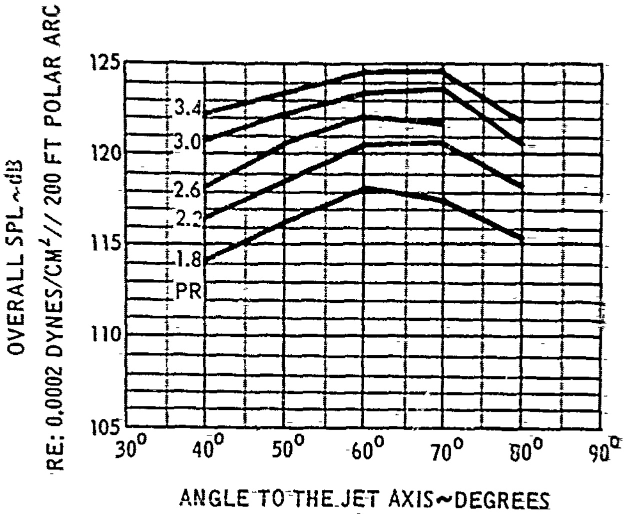


NOZZLE EXIT AREA (A8): 5.9 FT²

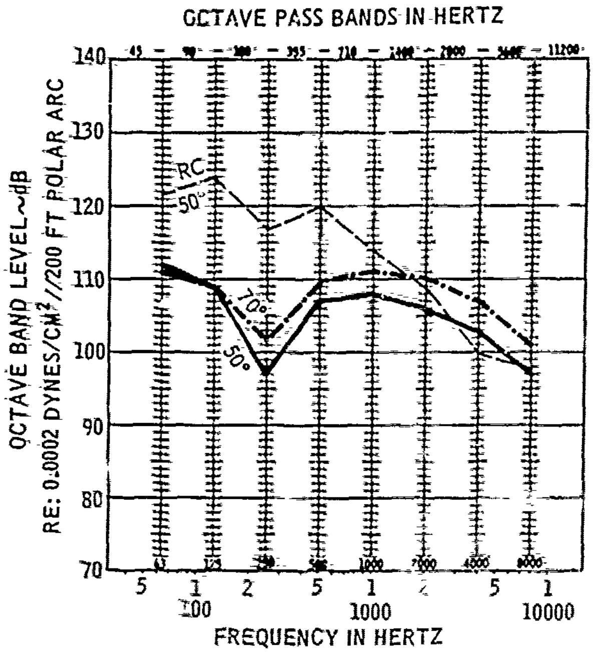


TOTAL TEMPERATURE (T8) 1500° F
NOZZLE EXIT AREA (A8): 5.. FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

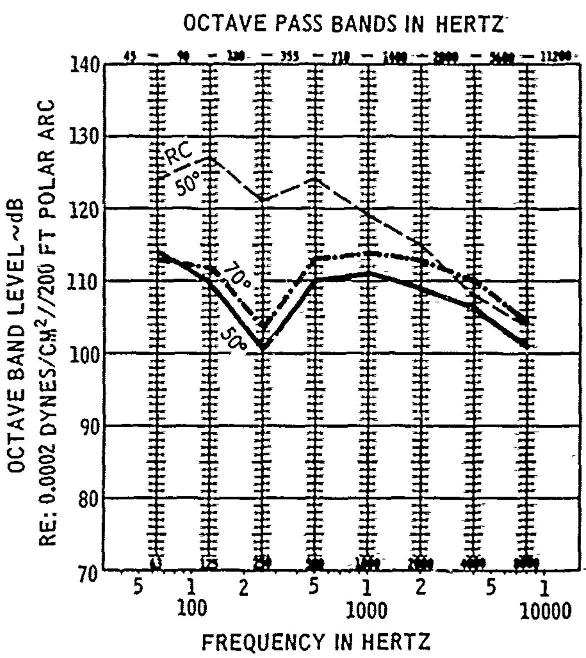


TOTAL TEMPERATURE (T_8): 1500°F
NOZZLE EXIT AREA (A_8): 5.9 FT²

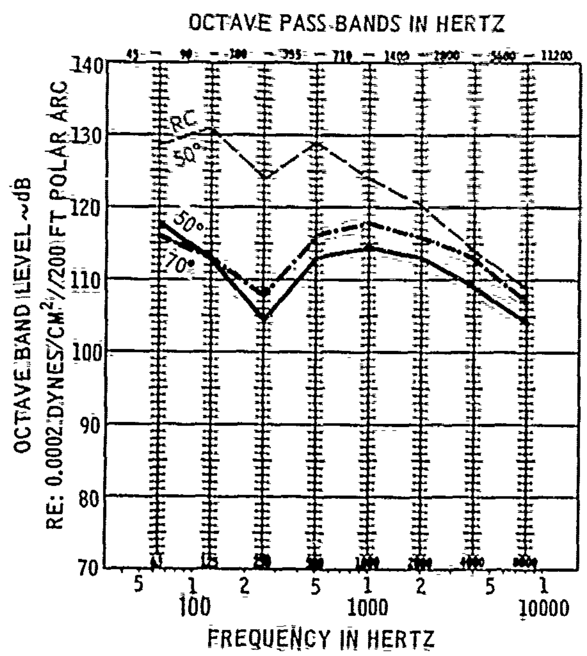


HM-AP-28 NOZZLE
(24 SPOKES)
AR 6.0
SCALE FACTOR: 8:1

PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1950 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2200 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2550 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-28

(24 Spokes, AR 6.0)

Remarks

Comparison of the 24-spoke area ratio 6.0 data with 24 spoke nozzles with area ratios of 1.9 (HM-AP-2) and 4.0 (HM-AP-32) indicate essentially no change in PNL suppression for these different area ratios. Blocking of the ventilation troughs did not affect PNL suppression values, see Reference D14.

Facility: Annex D (Cell #1)
Nozzle and Microphone Heights are 20 inches.

T_{amb}:

R.H.:

Date:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H 1062	1.8	1500°F	1950 fps	HM-AP-28
H 1063	2.2	"	2200	"
H 1064	2.6	"	2370	"
H 1061	3.0	"	2550	"
H 1065	3.4	"	2680	"
H 1036	1.8	1500°F	1950 fps	4.1 Inch Round Convergent Nozzle
H 1037	2.2	"	2200	"
H 1038	2.6	"	2370	"
H 1039	3.0	"	2550	"
H 1040	3.4	"	2680	"

Measured acoustic data is recorded in Reference D2.

NOZZLE TEST DATA

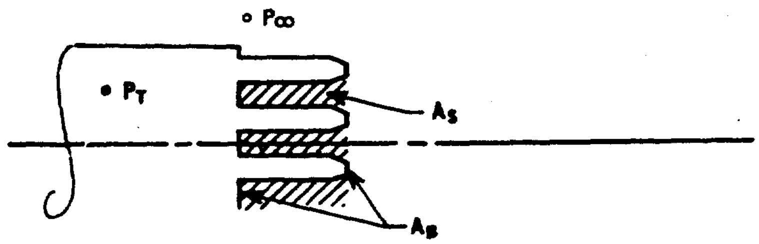
OCTAVE BAND LEVEL ~ dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-28

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H1062L40	114.0	110.0	104.0	97.5	104.5	106.0	105.0	102.0	95.0
H1062L50	116.2	112.0	109.0	97.0	107.0	108.0	106.0	103.0	97.0
H1062L60	118.1	112.0	110.0	102.0	110.0	111.0	109.5	106.0	100.0
H1062L70	117.8	111.8	109.0	102.0	109.5	111.0	110.0	107.0	101.0
H1062L80	115.2	109.0	107.0	101.5	106.0	108.0	108.0	103.0	95.0
H1063L40	116.4	112.0	106.0	99.0	107.0	109.0	108.0	105.0	99.0
H1063L50	118.6	114.0	110.0	100.5	110.0	111.0	109.0	106.5	101.0
H1063L60	120.6	115.0	112.5	104.0	113.0	113.0	112.0	108.0	103.0
H1063L70	120.6	113.0	112.0	104.0	113.0	114.0	113.0	110.0	104.0
H1063L80	118.4	111.0	110.0	104.0	110.0	112.0	111.0	107.0	98.0
H1064L40	118.1	114.0	108.0	100.0	109.0	110.5	109.0	106.0	100.0
H1064L50	120.6	116.0	112.0	102.5	112.5	113.0	111.0	108.0	103.0
H1064L60	122.1	116.0	113.0	106.0	114.5	115.0	113.0	110.0	105.0
H1064L70	121.9	114.0	112.5	106.0	114.0	116.0	114.0	111.0	106.0
H1064L80	123.1	112.0	110.0	104.0	121.0	113.0	113.0	108.5	100.0
H1061L40	120.9	117.0	111.5	103.0	111.0	113.0	112.0	108.0	101.5
H1061L50	122.2	118.0	113.0	104.5	113.0	114.5	113.0	109.0	104.0
H1061L60	123.5	118.0	15.0	108.0	116.0	116.0	114.0	111.0	105.0
H1061L70	123.7	116.0	113.5	108.0	116.0	118.0	116.0	113.0	107.0
H1061L80	120.5	113.0	11.0	106.0	109.0	115.0	114.0	110.0	101.0
H1065L40	122.3	119.0	114.0	105.0	112.0	114.0	111.0	108.0	101.0
H1065L50	123.5	120.0	115.0	106.0	114.0	115.0	113.0	109.0	104.0
H1065L60	124.7	120.0	116.0	108.0	117.5	117.0	114.0	111.0	106.0
H1065L70	124.7	113.0	114.0	115.0	117.5	113.0	118.0	115.5	112.0
H1065L80	121.9	115.0	112.0	107.0	114.0	116.0	114.0	110.0	101.5
H1036L40	127.9	122.0	125.0	117.5	118.0	112.0	107.0	0.0	0.0
H1036L50	127.6	121.5	124.0	117.0	120.0	114.0	109.0	100.0	98.0
H1036L60	124.5	118.0	120.0	114.0	118.0	113.0	108.0	99.0	95.0
H1036L70	120.6	118.5	115.0	109.0	115.0	111.5	107.0	99.5	0.0
H1036L80	117.3	109.0	110.0	105.5	113.0	109.0	106.0	97.0	90.0
H1037L40	131.3	125.0	128.0	121.0	123.0	118.0	113.0	105.0	0.0
H1037L50	131.0	124.0	127.0	121.0	124.0	119.0	115.0	108.0	104.0
H1037L60	129.0	121.0	124.0	118.0	124.0	118.0	115.0	107.0	[illegible]
H1037L70	124.2	116.0	118.0	118.0	119.0	116.0	112.5	105.5	100.0
H1037L80	121.1	111.0	112.5	109.0	117.0	114.0	111.0	102.0	94.0
H1038L40	133.1	127.0	129.5	122.0	125.0	120.0	116.0	108.0	108.0
H1038L50	133.5	127.0	129.0	123.0	127.0	122.0	118.0	112.0	107.0
H1038L60	131.2	123.0	126.0	121.0	126.0	121.0	118.0	111.0	106.0
H1038L70	127.3	119.0	121.0	116.0	122.0	119.0	116.0	110.0	104.0
H1038L80	124.1	113.0	115.0	112.0	119.0	118.0	116.0	108.0	100.0
H1039L40	134.5	128.0	131.0	123.0	127.0	122.0	118.0	111.0	110.0
H1039L50	135.2	128.5	130.5	124.0	129.0	124.0	121.0	114.0	109.0
H1039L60	133.4	126.0	128.0	123.0	128.0	123.0	120.0	114.0	108.0
H1039L70	129.6	121.0	123.0	118.0	124.0	122.0	119.0	113.0	108.0
H1039L80	126.3	115.0	116.0	114.0	121.0	121.0	118.0	110.0	103.0
H1040L40	134.9	129.0	131.0	124.0	127.0	123.0	119.0	112.0	110.0
H1040L50	135.9	129.0	131.0	125.0	130.0	125.0	122.0	115.0	110.0
H1040L60	134.1	127.0	128.0	124.0	129.0	124.0	121.0	115.0	109.0
H1040L70	130.5	121.0	123.0	119.5	125.0	123.5	121.0	114.5	109.5
H1040L80	128.5	116.0	117.0	116.0	123.0	124.0	120.0	113.0	105.0

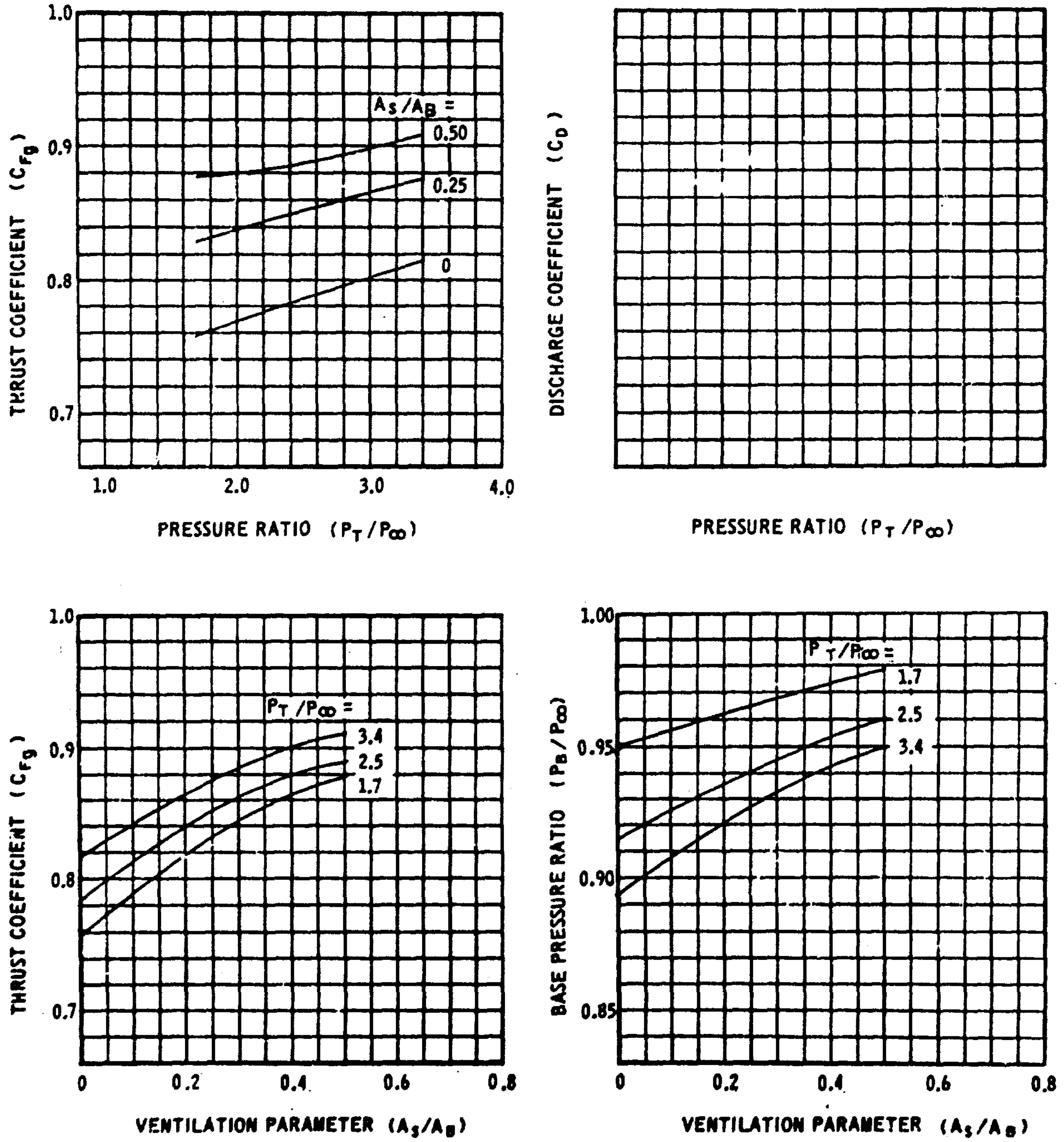
NOTE: DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-28

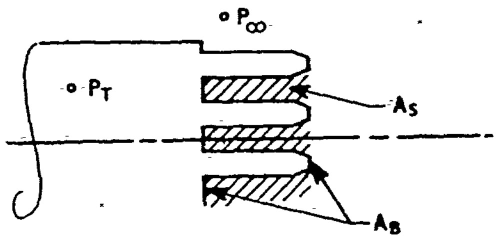


$$C_{F_g} = \frac{(\text{THRUST--DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



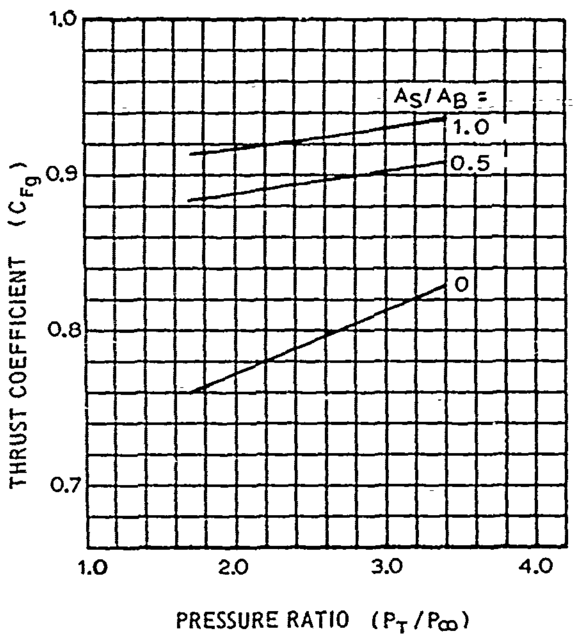
HM - AP - 29

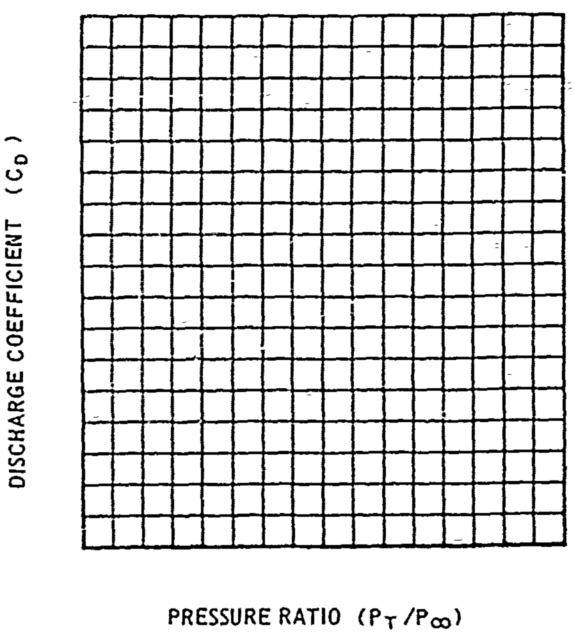


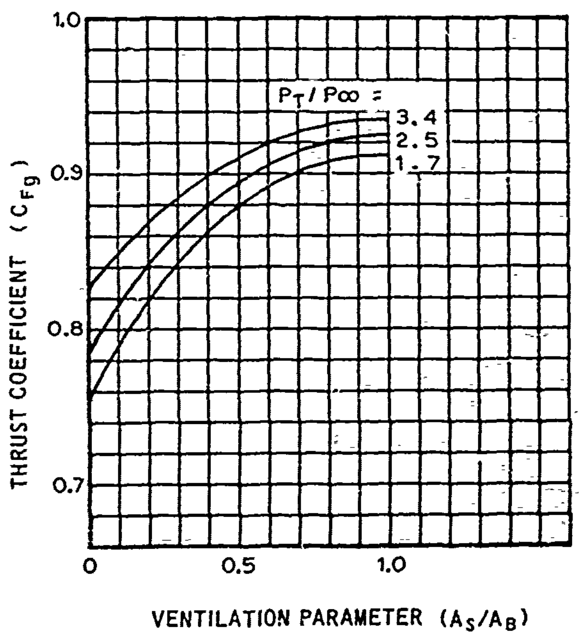
24 SPOKE NOZZLE
AREA RATIO = 6.0
NO EJECTOR

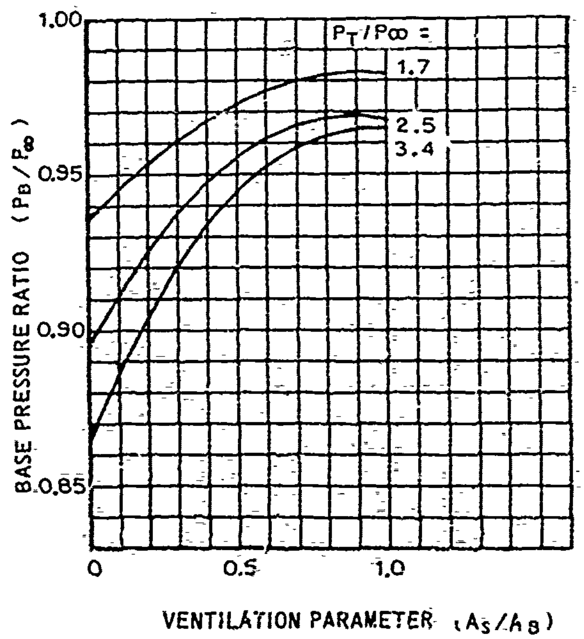
$$C_{F_g} = \frac{\text{(THRUST-DRAG) MEASURED}}{\text{IDEAL P[illegible]RY THRUST}}$$

$$C_D = \frac{\text{(MASS FLOW) MEASURED}}{\text{IDEAL PRIMARY MASS FLOW}}$$



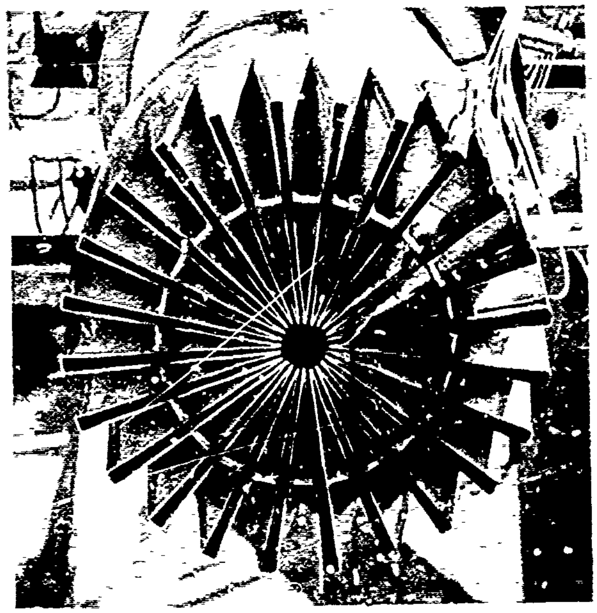






HM-AP-32 NOZZLE

(24 SPOKES AR 4.0)



Description:

Number of Elements: 24 spokes

Area Ratio: 4.0

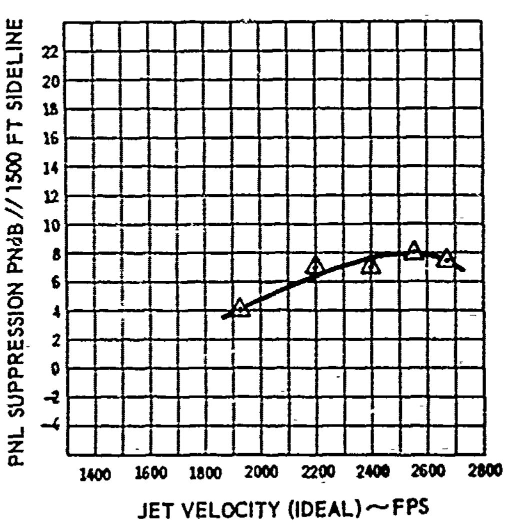
Spoke Penetration: 90%

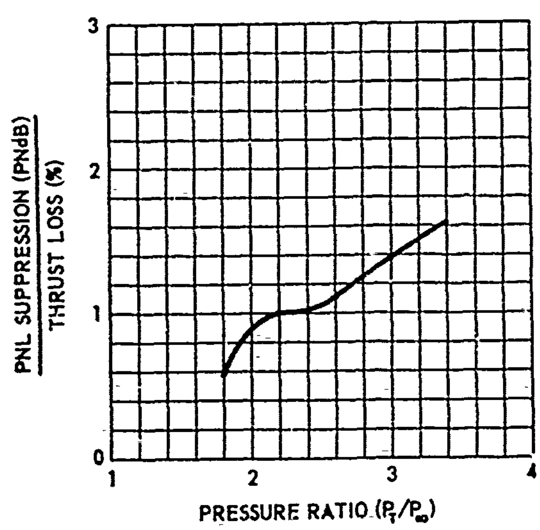
Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees

Ventilation Gutter Cant Angle: 28 degrees

Material: 321 CRES



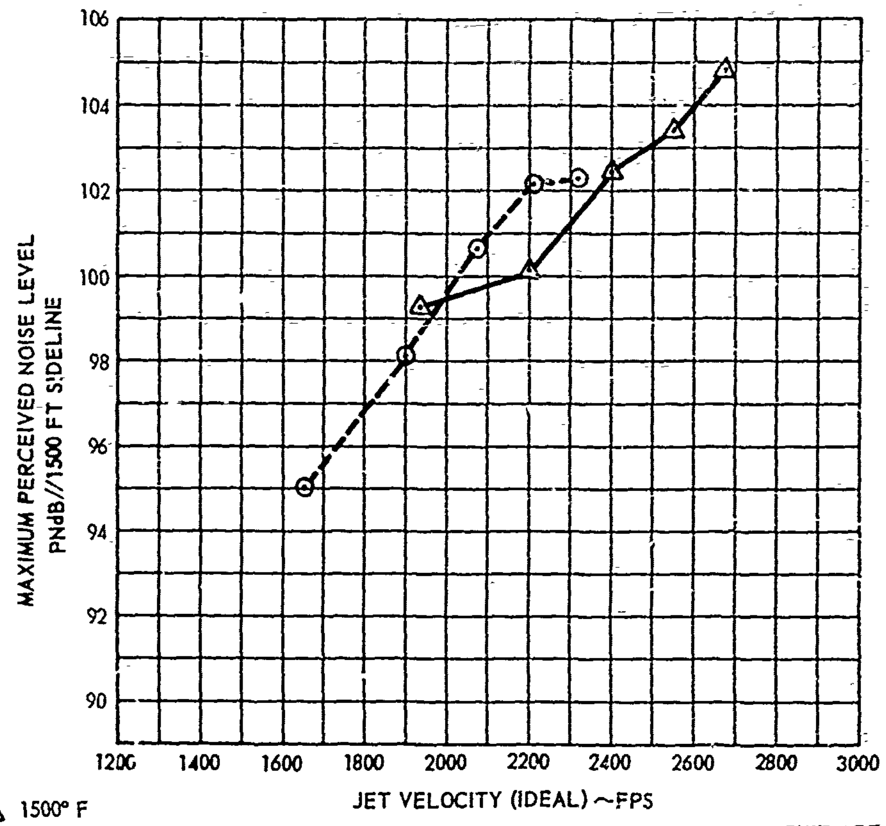


△—△ 1500° F

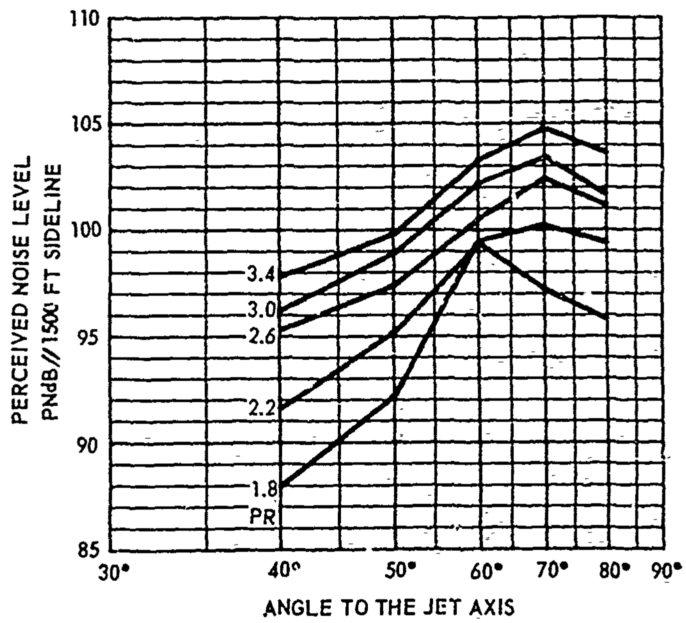
NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-32 NOZZLE
(24 SPOKES)
AR 4.0
SCALE FACTOR: 8:1

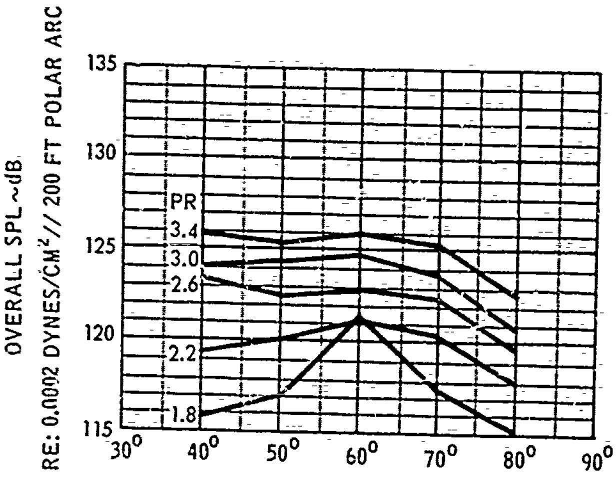


NOZZLE EXIT AREA (A_8): 5.9 FT^2

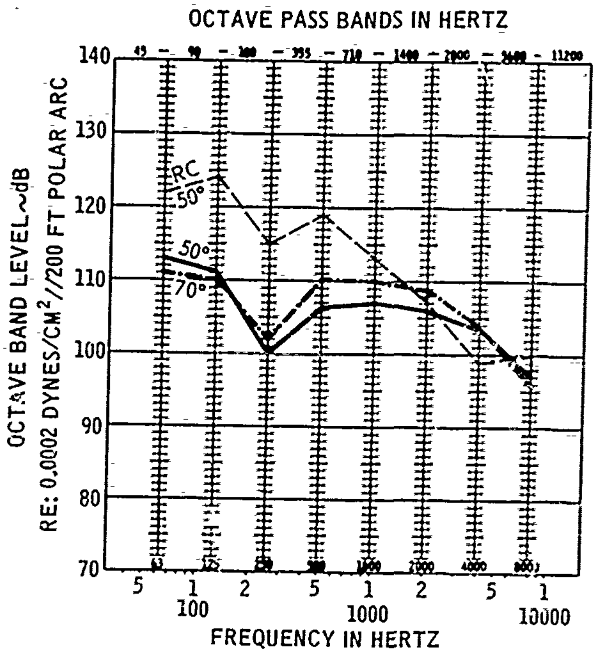


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

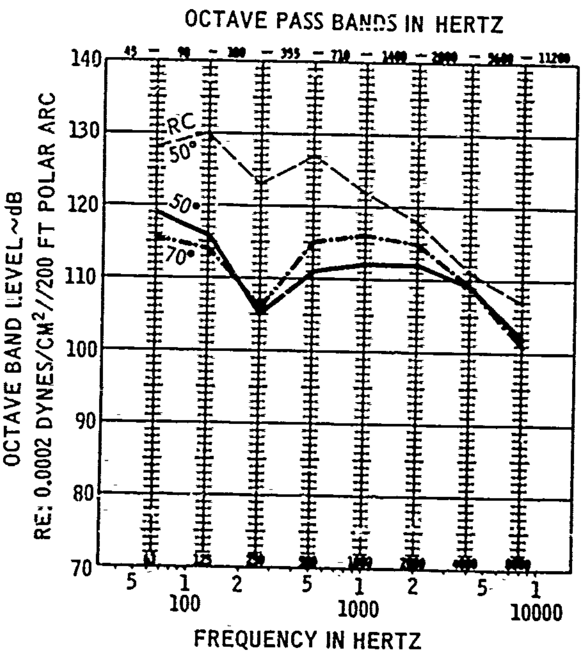


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

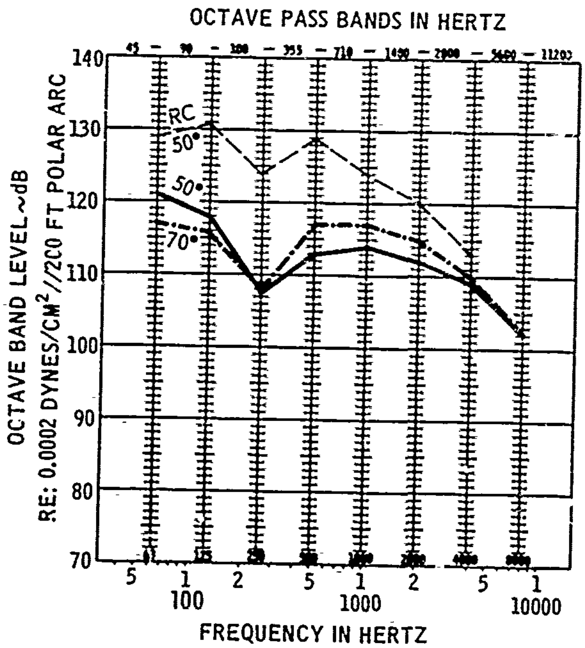


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

HM-AP-32 NOZZLE
(24 SPOKES)
AR 4.0
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-32 NOZZLE

(24 Spokes, AR = 4.0)

Remarks

The HM-AP-32 nozzle was tested with the ventilation troughs blocked, also. There was essentially no difference noted in the jet noise characteristics between the free and blocked ventilation cases. Another configuration of this nozzle utilized a cylinderical ejector 6.4 inches long and 9 inches in diameter (I.D.). The ejector was lined with 1 inch thick TWF fiberglass material contained by a 40% open area wire mesh. Considerable suppression of jet noise in the last four octave bands was noted with the ejector installed. The ejector was most beneficial at low angles to the jet axis, e.g. 6 to 9 dB suppression at 40°. At 70° to the jet axis the ejector had little influence on the jet noise spectrum, see Reference D15.

HM-AP-32

Test Facility: Annex D (Cell #1)
Nozzle and microphone height is 20 inches.

Date:

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_J (ideal)	Nozzle
H925	1.8	1000°F	1659 fps	HM-AP-32
H926	2.2	"	1900	"
H927	2.6	"	2073	"
H928	3.0	"	2205	"
H929	3.4	"	2311	"
H930	1.8	1500°F	1923	"
H931	2.2	"	2202	"
H932	2.6	"	2402	"
H933	3.0	"	2555	"
H934	3.4	"	2678	"
H982	1.8	1500°F	1923	4.1 Inch Round Convergent Nozzle
H983	2.6	"	2402	"
H984	3.0	"	2555	"
H985	3.4	"	2678	"

Acoustic data for these runs are recorded in Reference 2.

NOZZLE TEST DATA

OCTAVE BAND LEVEL ~ dB RE: 0.0002 DYNES/CM²//25 FT

HM-AP-32

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H925 L40	113.3	109.5	106.0	96.0	103.0	104.0	104.0	100.0	94.5
H925 L50	114.6	110.0	[illegible]	97.0	105.0	106.0	105.0	102.0	-0.0
H925 L60	115.8	109.0	108.0	100.0	108.0	108.0	109.0	103.0	95.0
H925 L70	114.6	107.0	106.0	98.0	107.0	108.0	108.0	102.0	94.0
H925 L80	112.1	105.0	104.0	96.0	104.0	105.0	105.0	100.0	91.0
H926 L40	117.6	115.0	109.0	99.0	105.0	107.0	107.0	104.5	98.0
H926 L50	117.7	113.0	110.5	99.5	107.5	109.0	109.0	106.0	99.0
H926 L60	119.2	113.0	111.0	103.0	111.0	112.0	112.0	106.0	99.0
H926 L70	117.8	110.0	109.0	100.0	110.0	111.5	111.0	106.0	98.0
H926 L80	115.5	107.0	106.5	99.0	107.5	109.0	109.0	105.0	95.0
H927 L40	122.3	121.0	111.0	101.0	106.5	109.0	111.0	105.5	100.0
H927 L50	120.4	116.0	113.0	102.0	109.0	112.0	112.0	108.0	101.5
H927 L60	121.3	115.5	113.0	105.0	112.0	114.0	114.0	109.0	101.0
H927 L70	120.4	113.0	111.0	103.0	112.0	114.0	114.0	109.0	101.0
H927 L80	118.0	110.0	108.0	101.0	109.0	112.0	112.0	107.0	98.0
H928 L40	122.0	118.0	115.0	105.0	110.5	113.0	113.0	109.0	101.0
H928 L50	122.0	118.0	115.0	104.0	111.0	113.0	113.0	109.0	102.0
H928 L60	122.7	117.0	115.0	107.5	114.0	115.0	115.0	109.0	102.0
H928 L70	121.9	114.0	113.0	104.5	114.0	116.0	115.0	110.0	102.0
H928 L80	119.4	111.0	109.0	102.5	111.0	114.0	113.0	108.0	99.0
H929 L40	123.9	121.0	117.0	107.0	111.5	114.0	113.0	109.0	-0.0
H929 L50	122.9	119.0	116.0	107.0	113.0	114.0	112.0	109.0	102.0
H929 L60	123.5	119.0	116.0	109.0	115.0	115.0	114.0	109.0	102.0
H929 L70	122.4	115.5	114.0	106.0	115.0	116.0	114.5	109.0	102.0
H929 L80	120.0	112.0	110.0	104.0	113.0	114.0	113.0	108.0	99.0
H930 L40	115.7	112.0	109.0	99.5	105.0	106.0	106.0	102.0	-0.0
H930 L50	117.0	113.0	111.0	100.0	106.5	107.0	106.0	103.5	97.0
H930 L60	121.4	113.0	111.5	104.0	110.5	119.0	109.0	104.0	97.0
H930 L70	117.4	111.0	110.0	102.0	110.0	110.0	109.0	104.0	96.0
H930 L80	115.0	108.0	107.0	100.0	108.0	108.0	107.0	102.0	93.0
H931 L40	119.3	116.0	112.0	102.0	108.0	109.0	109.0	106.0	99.0
H931 L50	120.0	116.0	114.0	103.0	109.0	110.0	109.5	107.0	109.0
H931 L60	121.3	116.0	114.0	107.0	113.0	113.0	112.5	108.0	100.0
H931 L70	120.3	113.5	112.0	104.0	113.0	114.0	112.0	107.5	99.5
H931 L80	118.0	110.5	109.0	102.0	111.0	111.0	111.0	106.0	96.5
H932 L40	123.2	121.0	116.0	105.0	109.0	111.0	111.5	108.0	-0.0
H932 L50	122.5	119.0	116.0	105.0	111.0	112.0	112.0	109.0	102.0
H932 L60	122.9	118.5	116.0	108.0	113.0	114.0	114.0	109.0	101.0
H932 L70	122.5	115.5	114.0	106.0	115.0	116.0	115.0	109.0	101.0
H932 L80	119.7	112.0	111.0	103.0	112.0	113.0	113.0	108.0	99.0
H933 L40	124.0	121.0	112.0	107.5	111.0	113.0	112.5	108.0	-0.0
H933 L50	124.2	121.0	118.0	107.5	113.0	114.0	112.0	109.0	102.0
H933 L60	124.6	120.0	118.0	111.0	116.0	115.0	115.0	110.0	103.0
H933 L70	123.8	117.0	116.0	108.0	117.0	117.0	115.0	110.0	102.0
H933 L80	120.7	113.0	112.0	105.0	113.0	115.0	113.0	108.5	100.0
H934 L40	125.9	123.0	120.0	109.0	113.0	115.0	114.0	109.5	-0.0
H934 L50	125.2	122.0	119.0	109.0	114.0	115.0	113.0	110.0	-0.0
H934 L60	126.0	122.0	119.0	112.0	117.0	116.0	116.0	110.0	104.0
H934 L70	125.3	119.0	117.5	110.0	118.5	118.0	116.5	111.0	104.0
H934 L80	122.6	115.0	114.0	107.0	115.0	116.5	115.0	110.0	101.0
H982 L40	127.8	122.0	125.0	117.0	118.0	111.0	105.0	96.0	103.0
H982 L50	127.4	122.0	124.0	115.0	119.0	113.0	107.0	99.0	100.0
H982 L60	123.5	118.0	119.0	110.0	117.0	112.0	106.0	97.5	98.0

NOTE: DATA INCLUDES GROUND REFLECTION INTERFERENCE

NOZZLE TEST DATA

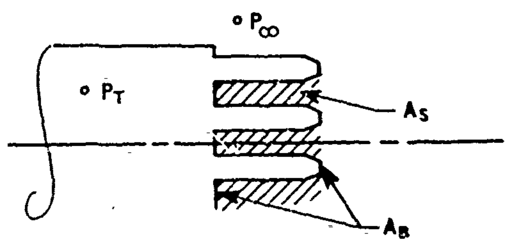
OCTAVE BAND LEVEL—dB RE: 0.0002 DYNES/CM²//25 FT

HM–AP–32

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H982 L70	120.2	113.5	114.0	109.0	115.0	111.0	107.0	98.0	95.0
H982 L80	116.7	109.0	109.0	106.0	112.0	109.0	104.0	95.0	89.0
H983 L40	133.5	127.0	130.0	123.0	125.5	120.5	116.0	108.0	-0.0
H983 L50	134.1	128.0	130.0	123.0	127.0	122.0	118.0	111.0	107.0
H983 L60	131.3	124.0	126.0	118.5	126.0	122.0	117.0	110.0	105.0
H983 L70	127.7	119.0	121.0	116.0	123.0	119.0	117.0	110.0	105.0
H983 L80	124.6	114.0	115.0	112.0	119.5	119.0	116.0	108.0	101.0
H984 L40	134.8	129.0	131.0	124.0	127.0	122.0	118.0	110.0	-0.0
H984 L50	135.4	129.0	131.0	124 0	129.0	124.0	120.0	113.0	-0.0
H984 L60	132.6	126.0	127.0	120.0	127.0	123.0	119.0	113.0	107.0
H984 L70	129.6	121.0	123.0	119.0	124.0	122.0	119.0	113.0	108.0
H984 L80	127.7	116.0	116.0	115.0	122.0	122.0	119.0	118.0	111.0
H985 L40	135.8	130.0	132.0	125.0	128.0	123.0	119.0	111.0	-0.0
H985 L50	136.8	131.0	132.0	126.0	130.0	125.0	122.0	115.0	-0.0
H985 L60	133.8	127.5	128.0	122.0	128.0	124.0	121.0	114.0	-0.0
H985 L70	130.9	123.0	124.0	120.0	125.0	123.0	121.0	114.0	-0.0
H985 L80	128.4	117.0	117.0	116.0	123.0	124.0	119.0	112.0	-0.0

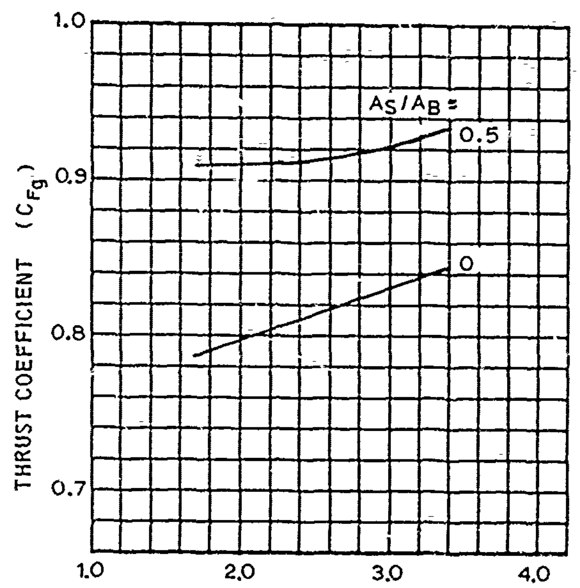
NOTE: DATA INCLUDES GROUND REFLECTION INTERFERENCE

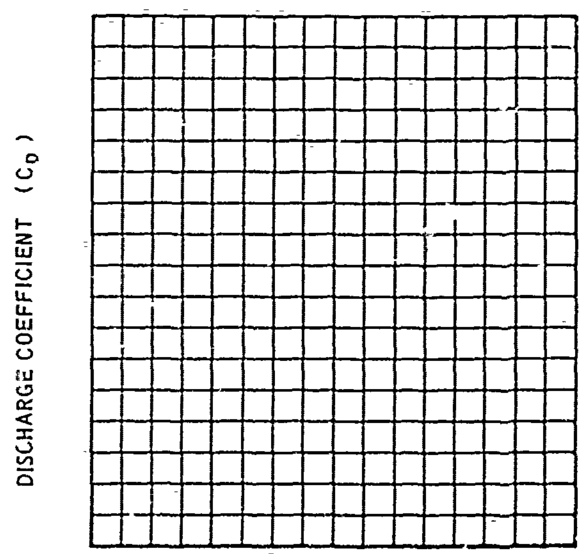
HM - AP - 32

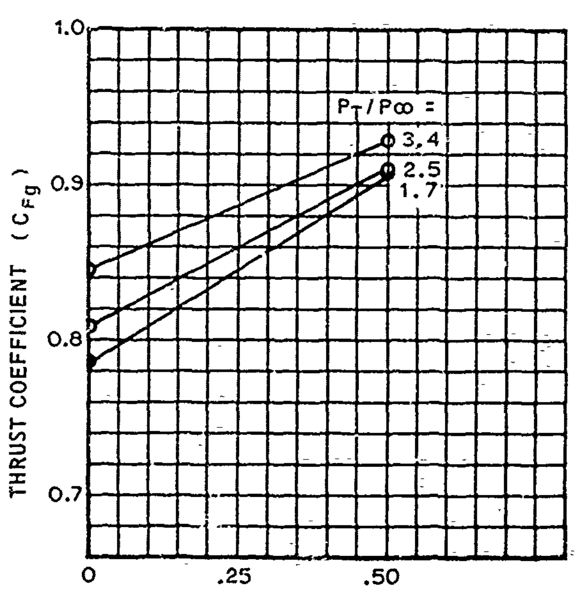


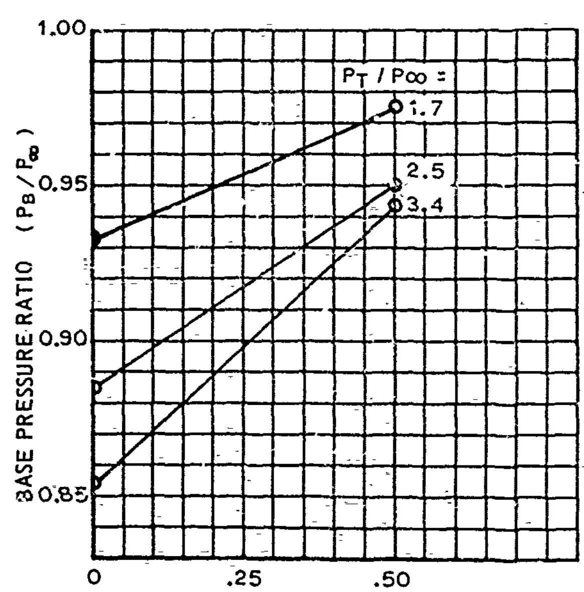
$$C_{F_g} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$

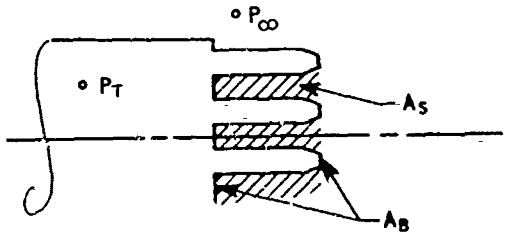








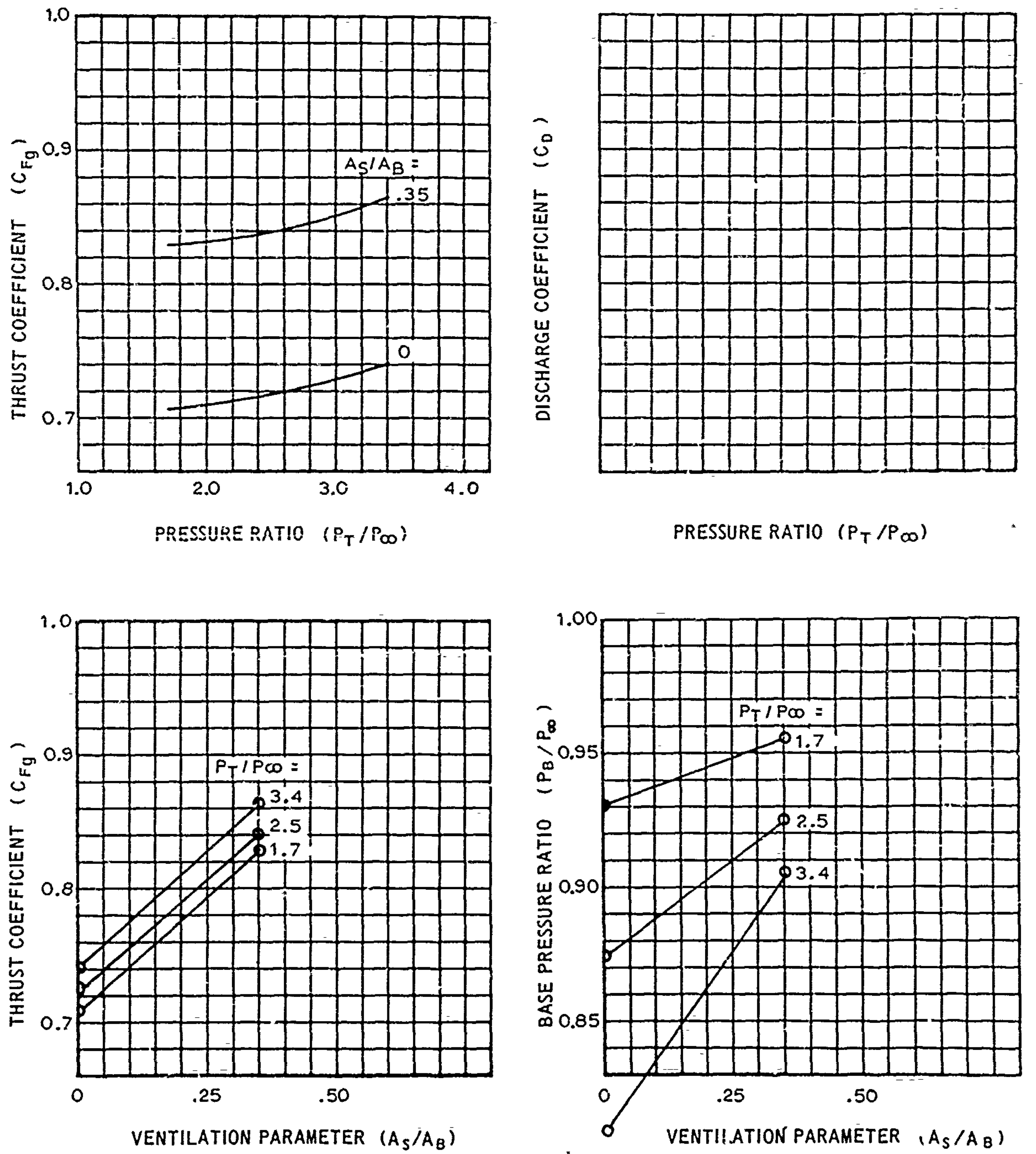
HM-AP-33



36 SPOKE NOZZLE
AREA RATIO = 4.0
NO EJECTOR

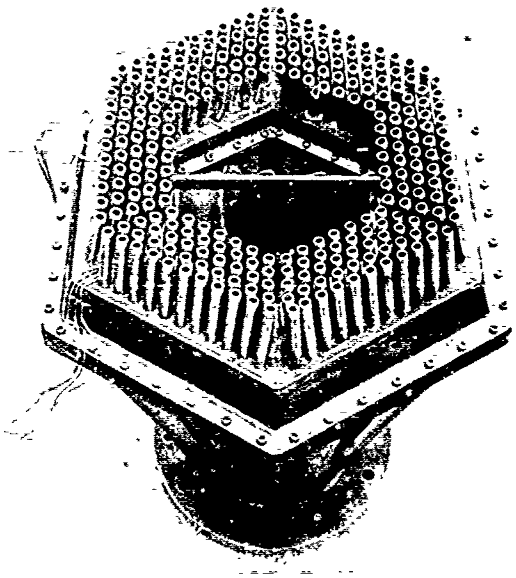
$$C_{F_g} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



HM-AP-35 NOZZLE

(270 TUBE HEXAGONAL ANNULUS ARRAY AR 7.0)



Description:

The HM-AP-35 nozzle consists of a hexagonal annulus array containing 270 equally spaced round convergent tubes through which passes the primary flow. Six hollow struts leading from the outside wall to the central region provide ambient air to this low pressure area.

Number of Elements: 270 tubes with RC ends

Area Ratio: 7.0

Flow Area: 28.3 square inches

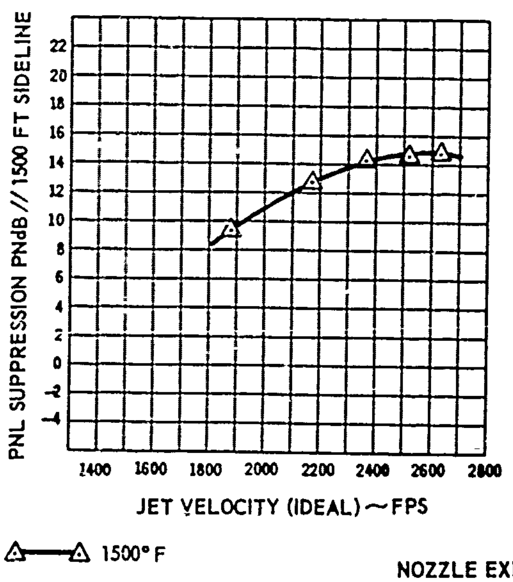
Exit Cant Angle: 15 degrees (inwards)

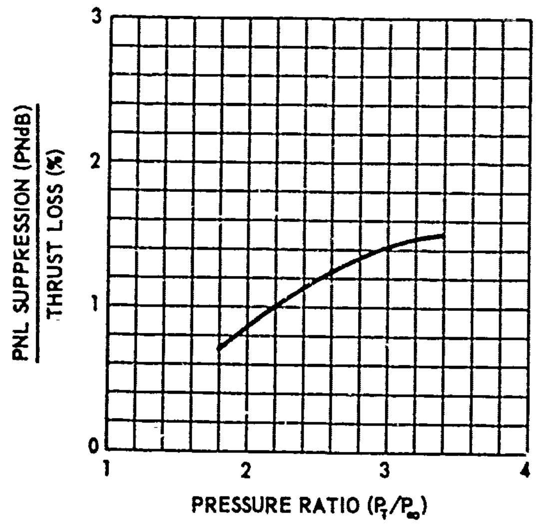
Tube Spacing Ratio: 2 (equivalent to a local area ratio of 4.0)

Tube Exit Diameter: 0.366 inches

Tube Length: 2.745 inches

Material: 321 CRES

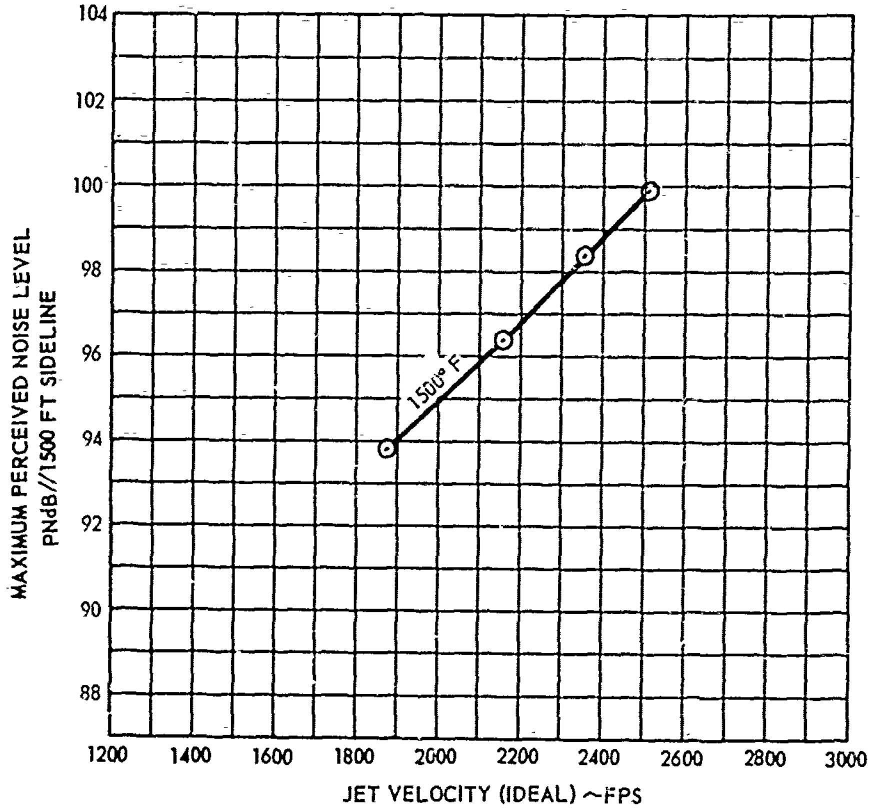




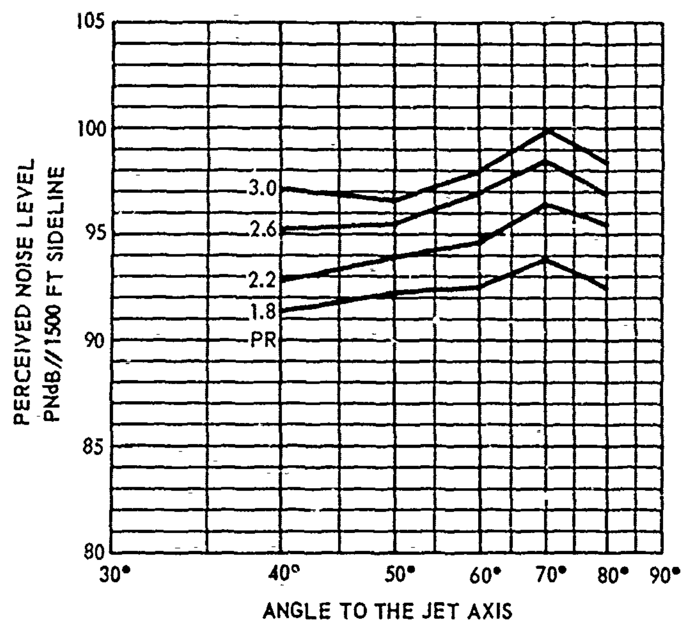
NOZZLE EXIT AREA (A_e): 12.6 FT²

FREE FIELD VALUES

HM-AP-35 NOZZLE
(270 TUBE ANNULUS)
AR 7.0
SCALE FACTOR: 8:1



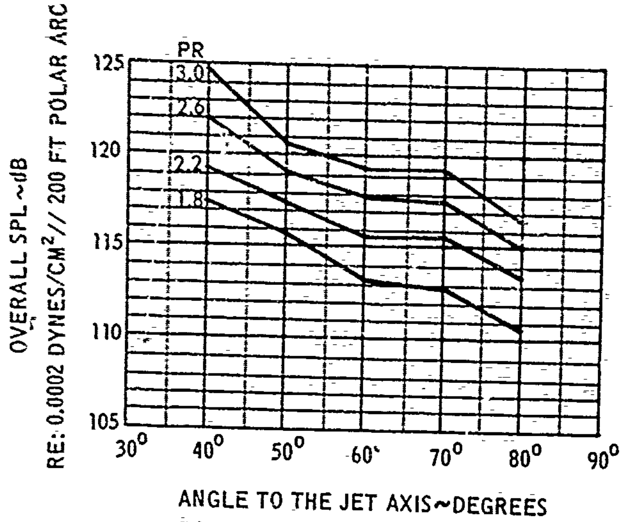
NOZZLE EXIT AREA (A_8): 12.6 FT^2



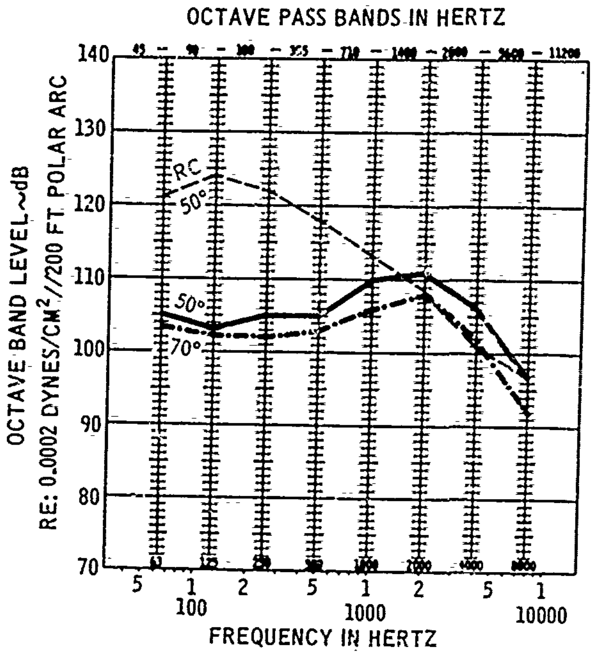
TOTAL TEMPERATURE (T_8): 1500° F

NOZZLE EXIT AREA (A_8): 12.6 FT^2

FREE FIELD VALUES

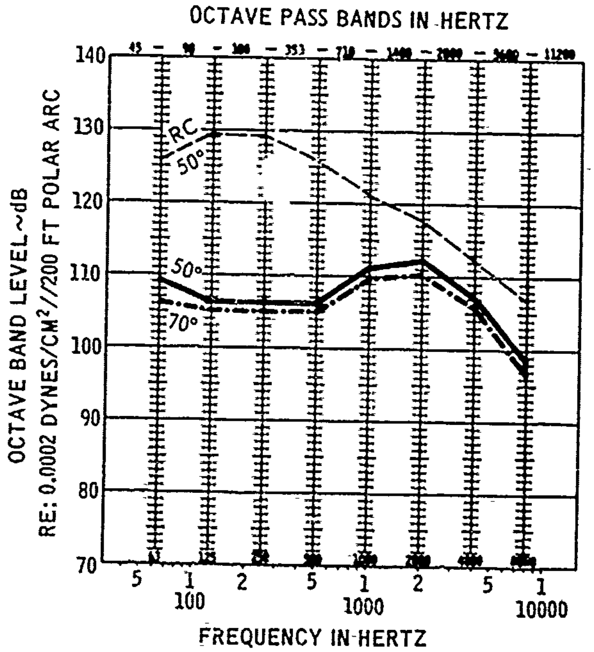


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT²

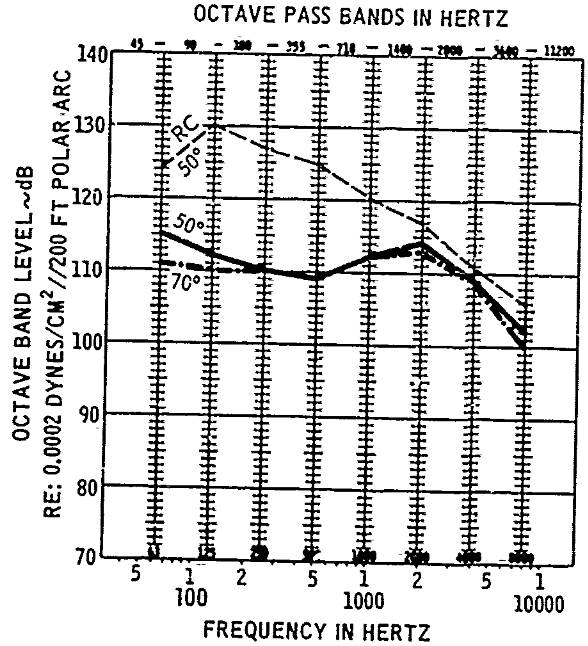


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1878 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²

HM-AP-35 NOZZLE
(270 TUBE ANNULUS)
AR 7.0
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2171 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2507 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

HM-AP-35 NOZZLE

(270 Tube Hexagonal Annulus)

Remarks

Several other configurations of the HM-AP-35 Nozzle were tested. One configuration had 240 tubes, where the flow in 5 tubes at each corner of the hexagon array was blocked. This was done to reduce the jet flow interaction. The 240 tube configuration had 0.5 to 1.0 PNdB less suppression relative to the 270 tube configuration.

Another configuration had a conical plug installation in the center of the annulus. Plug length was equal to the annulus outer diameter. Noise suppression decreased by 1.5 to 3.5 PNdB relative to the 270 tube configuration without the plug.

Other configurations used plug lengths that were 40% and 60% of the previous configuration. A slight decrease in PNL suppression was noted as plug length was shortened. See Reference D16.

HM-AP-35 NOZZLE

Test Facility: (HNTF)

Date: Sept. 10, 1968 (279.1-281.5), Sept. 20, 1968 (293.1-293.5)

T_{amb}: 66°F (279.1-281.5) : 58°F (293.1-293.5)

R.H.: 69% (279.1-281.5) : 65% (293.1-293.5)

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
279.1	3.385	491°F	1837 fps	HM-AP-35
279.2	2.976	489	1750	"
279.3	2.589	490	1650	"
279.4	2.200	489	1535	"
279.5	1.803	486	1328	"
280.2	2.986	974	2164	"
280.3	2.596	965	2032	"
280.4	2.198	952	1858	"
280.5	1.804	956	1630	"
281.1	3.381	1450	2628	"
281.2	2.982	1449	2507	"
281.3	2.597	1434	2353	"
281.4	2.202	1453	2171	"
281.5	1.793	1430	1878	"
293.1	1.788	1430	1875	6 inch Round Convergent Nozzle
293.2	2.198	1441	2162	" " "
293.3	2.592	1440	2354	" " "
293.4	2.985	1452	2510	" " "
293.5	3.362	1461	2631	" " "

HM-AP-35 NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/ CM^2 // 25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
279.1 L40	121.3	116.1	112.0	108.8	108.9	112.7	115.1	110.1	102.4
279.1 L50	118.0	111.0	110.0	108.0	107.0	110.0	111.0	106.0	100.0
279.1 L60	116.5	108.0	108.0	107.0	106.0	109.0	110.0	106.0	99.0
279.1 L70	116.3	108.0	107.0	106.0	107.0	109.0	110.0	106.0	98.0
279.1 L80	113.9	106.0	104.0	104.0	104.0	107.0	107.0	104.0	96.0
279.2 L40	120.2	112.7	109.1	106.5	107.4	112.6	115.5	111.0	103.2
279.2 L50	117.5	109.0	108.0	107.0	106.0	110.0	112.0	108.0	101.0
279.2 L60	115.9	107.0	106.0	105.0	105.0	109.0	109.0	108.0	101.0
279.2 L70	116.5	106.0	105.0	105.0	106.0	110.0	111.0	108.0	100.0
279.2 L80	113.7	104.0	102.0	103.0	103.0	107.0	108.0	105.0	96.0
279.3 L40	117.0	110.3	106.6	104.0	104.1	109.3	111.8	107.0	98.3
279.3 L50	115.2	107.0	107.0	105.0	104.0	107.0	109.0	106.0	97.0
279.3 L60	113.0	105.0	104.0	103.0	102.0	106.0	105.0	105.0	97.0
279.3 L70	113.8	104.0	103.0	102.0	103.0	107.0	109.0	104.0	95.0
279.3 L80	111.3	102.0	99.0	100.0	100.0	105.0	106.0	102.0	95.0
279.4 L40	116.6	109.1	104.2	102.8	103.4	109.3	111.9	107.3	99.1
279.4 L50	114.4	108.0	105.0	104.0	103.0	106.0	108.0	105.0	96.0
279.4 L60	113.1	104.0	103.0	102.0	102.0	107.0	106.0	105.0	97.0
279.4 L70	112.5	103.0	100.0	100.0	101.0	106.0	108.0	103.0	93.0
279.4 L80	109.1	99.0	97.0	97.0	98.0	103.0	104.0	100.0	91.0
279.5 L40	114.2	108.3	103.0	101.5	102.0	106.9	108.4	103.7	94.6
279.5 L50	112.0	107.0	103.0	101.0	100.0	103.0	105.0	101.0	92.0
279.5 L60	109.9	102.0	100.0	100.0	99.0	103.0	103.0	101.0	92.0
279.5 L70	108.8	101.0	97.0	97.0	99.0	102.0	103.0	99.0	89.0
279.5 L80	106.4	97.0	94.0	94.0	95.0	101.0	101.0	97.0	87.0
280.1 L40	124.3	121.0	115.5	111.6	110.0	114.0	116.0	111.0	103.0
280.1 L50	120.0	115.0	112.0	110.0	109.0	111.0	112.0	107.0	99.0
280.1 L60	120.0	113.0	112.0	111.0	110.0	112.0	112.0	109.0	101.0
280.1 L70	118.5	111.0	110.0	109.0	108.0	111.0	112.0	107.0	99.0
280.1 L80	116.1	108.0	106.0	106.0	106.0	109.0	110.0	106.0	98.0
280.2 L40	122.3	118.0	112.0	109.0	109.0	113.0	116.0	111.0	103.0
280.2 L50	119.2	113.0	110.0	108.0	107.0	111.0	113.0	109.0	101.0
280.2 L60	118.4	110.0	109.0	109.0	108.0	111.0	112.0	109.0	101.0
280.2 L70	117.9	109.0	108.0	107.0	108.0	111.0	112.0	108.0	100.0
280.2 L80	115.7	106.0	105.0	105.0	105.0	109.0	110.0	107.0	100.0
280.3 L40	120.8	114.0	109.0	106.0	107.0	113.0	116.0	112.0	104.0
280.3 L50	118.1	110.0	107.0	106.0	106.0	111.0	113.0	109.0	101.0
280.3 L60	117.9	108.0	107.0	107.0	107.0	111.0	112.0	110.0	102.0
280.3 L70	117.5	106.0	106.0	105.0	106.0	110.0	113.0	110.0	101.0
280.3 L80	114.7	104.0	102.0	102.0	103.0	108.0	110.0	107.0	99.0
280.4 L40	119.1	110.0	105.0	104.0	106.0	112.0	115.0	111.0	102.7
280.4 L50	116.6	106.0	105.0	104.0	105.0	110.0	112.0	108.0	100.0
280.4 L60	115.2	104.0	104.0	105.0	104.0	108.0	110.0	107.0	99.0
280.4 L70	114.9	104.0	104.0	104.0	104.0	108.0	110.0	106.0	97.0
280.4 L80	112.1	102.0	100.0	100.0	101.0	106.0	107.0	103.0	94.0
280.5 L40	115.0	105.0	101.0	101.0	103.0	109.0	111.0	105.0	96.0
280.5 L50	113.3	103.0	102.0	103.0	103.0	107.0	108.0	103.0	94.0
280.5 L60	110.8	100.0	101.0	102.0	101.0	104.0	105.0	100.0	91.0
280.5 L70	110.3	100.0	100.0	100.0	100.0	104.0	105.0	100.0	90.0
280.5 L80	108.0	98.0	97.0	97.0	97.0	103.0	102.0	97.0	87.0
281.1 L40	126.2	124.0	118.0	113.0	112.0	114.0	115.0	110.0	102.0
281.1 L50	113.0	109.0	106.0	103.0	101.0	103.0	103.0	97.0	90.0
281.1 L60	119.7	114.0	112.0	111.0	109.0	111.0	111.0	107.0	100.0
281.1 L70	119.5	113.0	111.0	111.0	110.0	111.0	112.0	107.0	98.0
281.1 L80	117.1	110.0	108.0	107.0	107.0	110.0	110.0	106.0	98.0
281.2L40	124.7	122.0	115.0	111.0	111.0	114.0	116.0	111.0	103.0
281.2L50	120.6	115.0	112.0	110.0	109.0	112.0	114.0	109.0	102.0
281.2L60	119.3	112.0	110.0	111.0	109.0	111.0	112.0	109.0	102.0
281.2L70	119.3	111.0	110.0	110.0	109.0	112.0	113.0	109.0	100.0
281.2L80	116.5	108.0	107.0	106.0	106.0	110.0	110.0	107.0	99.0

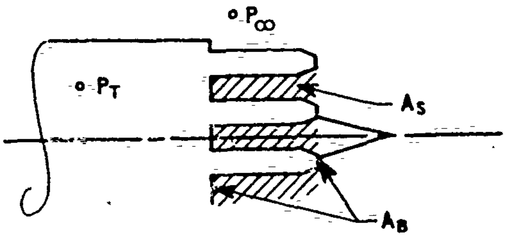
NOTE: THESE ARE FREE FIELD VALUES

HM-AP-35 NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
281.3L40	121.9	117.0	111.0	108.0	109.0	114.0	116.0	111.0	103.0
281.3L50	119.2	113.0	110.0	108.0	107.0	111.0	113.0	109.0	100.0
281.3L60	117.8	110.0	108.0	109.0	108.0	110.0	111.0	108.0	100.0
281.3L70	117.5	109.0	107.0	108.0	107.0	110.0	112.0	107.0	98.0
281.3L80	114.9	107.0	105.0	104.0	104.0	108.0	109.0	105.0	97.0
281.4L40	119.3	113.0	107.0	105.0	105.0	112.0	114.0	110.0	102.0
281.4L50	117.3	109.0	106.0	106.0	106.0	111.0	112.0	107.0	98.0
281.4L60	115.5	107.0	105.0	107.0	105.0	108.0	109.0	106.0	98.0
281.4L70	115.5	106.0	105.0	105.0	105.0	109.0	110.0	106.0	96.0
281.4L80	113.4	104.0	102.0	102.0	102.0	107.0	108.0	105.0	95.0
281.5L40	117.6	108.0	102.0	103.0	105.0	111.0	114.0	108.0	100.0
281.5L50	115.8	105.0	103.0	105.0	105.0	110.0	111.0	106.0	96.0
281.5L60	113.3	103.0	102.0	105.0	104.0	107.0	107.0	103.0	95.0
281.5L70	112.8	103.0	102.0	102.0	103.0	106.0	108.0	102.0	92.0
281.5L80	110.6	102.0	99.0	99.0	99.0	105.0	105.0	100.0	91.0
293.1L40	131.4	127.0	126.0	125.0	121.0	114.0	109.0	101.0	97.0
293.1L50	128.0	121.0	124.0	122.0	118.0	113.0	109.0	101.0	97.0
293.1L60	124.5	116.0	118.0	119.0	117.0	115.0	111.0	103.0	97.0
293.1L70	122.8	114.0	115.0	117.0	116.0	115.0	110.0	104.0	93.0
293.1L80	119.3	111.0	111.0	113.0	114.0	111.0	74.0	101.0	94.0
293.2L40	136.1	131.0	129.0	131.0	127.0	123.0	118.0	111.0	106.0
293.2L50	134.0	125.0	129.0	129.0	126.0	121.0	118.0	112.0	107.0
293.2L60	129.4	119.0	122.0	124.0	123.0	121.0	117.0	111.0	105.0
293.2L70	127.4	116.0	118.0	121.0	121.0	121.0	117.0	111.0	100.0
293.2L80	123.7	114.0	115.0	117.0	118.0	116.0	113.0	107.0	101.0
293.3L40	137.9	134.0	132.0	131.0	127.0	123.0	118.0	112.0	107.0
293.3L50	136.7	127.0	131.0	132.0	129.0	125.0	121.0	115.0	111.0
293.3L60	131.5	121.0	124.0	126.0	125.0	123.0	120.0	114.0	108.0
293.3L70	129.6	118.0	120.0	123.0	124.0	123.0	119.0	113.0	103.0
293.3L80	126.7	115.0	116.0	120.0	122.0	119.0	116.0	111.0	104.0
293.4L40	141.1	137.0	137.0	132.0	129.0	125.0	120.0	113.0	109.0
293.4L50	139.5	130.0	136.0	133.0	131.0	126.0	123.0	117.0	112.0
293.4L60	134.7	124.0	128.0	129.0	128.0	126.0	123.0	117.0	111.0
293.4L70	132.5	121.0	124.0	126.0	126.0	126.0	122.0	116.0	107.0
293.4L80	129.2	118.0	120.0	122.0	124.0	122.0	119.0	113.0	107.0
293.5L40	141.6	138.0	137.0	133.0	129.0	125.0	121.0	113.0	109.0
293.5L50	139.9	131.0	136.0	134.0	131.0	127.0	124.0	118.0	113.0
293.5L60	135.7	125.0	129.0	130.0	129.0	127.0	124.0	118.0	113.0
293.5L70	133.8	123.0	125.0	127.0	128.0	127.0	123.0	117.0	107.0
293.5L80	130.9	119.0	122.0	124.0	126.0	123.0	120.0	114.0	108.0

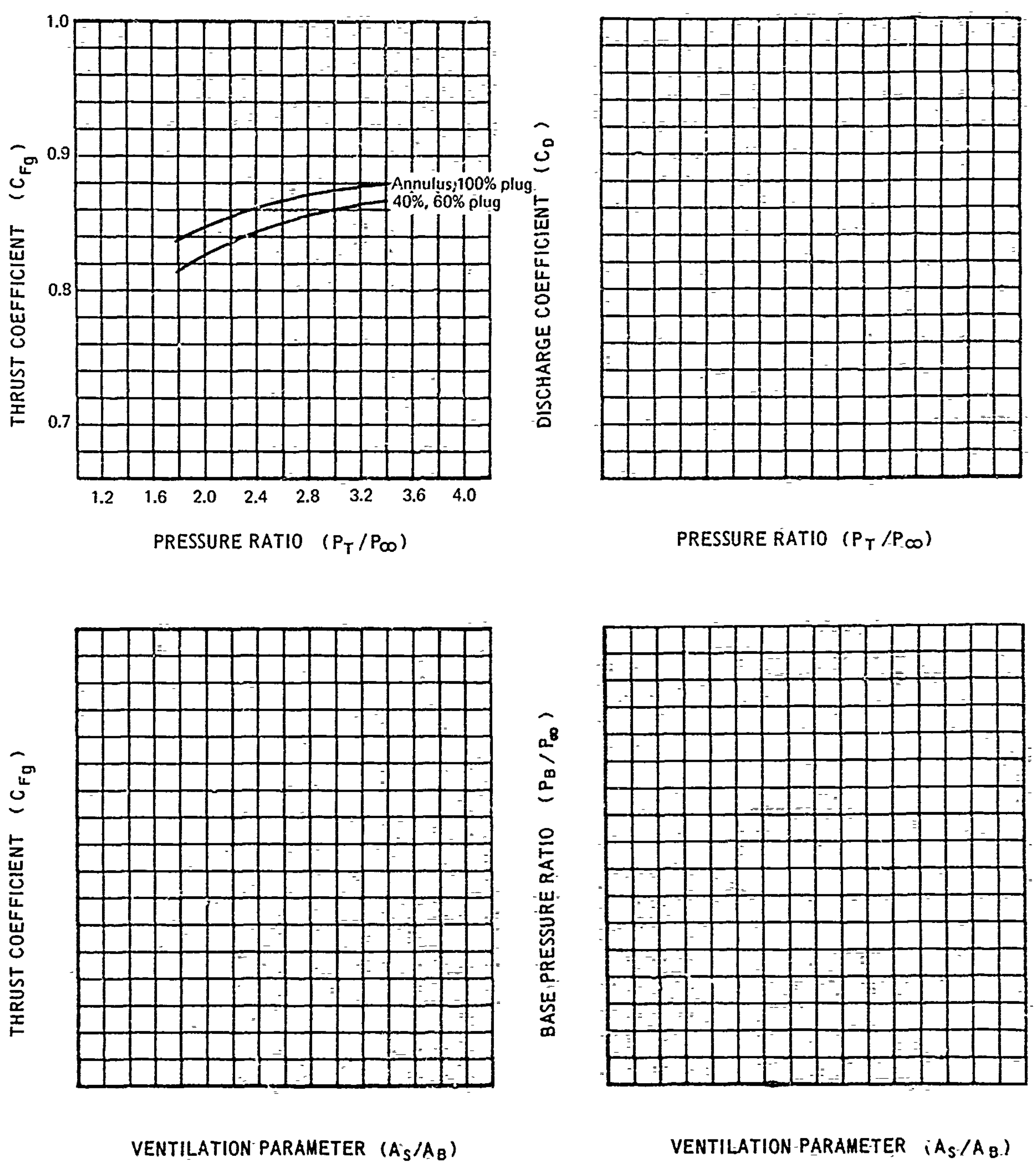
NOTE: THESE ARE FREE FIELD VALUES

HM-AP-35



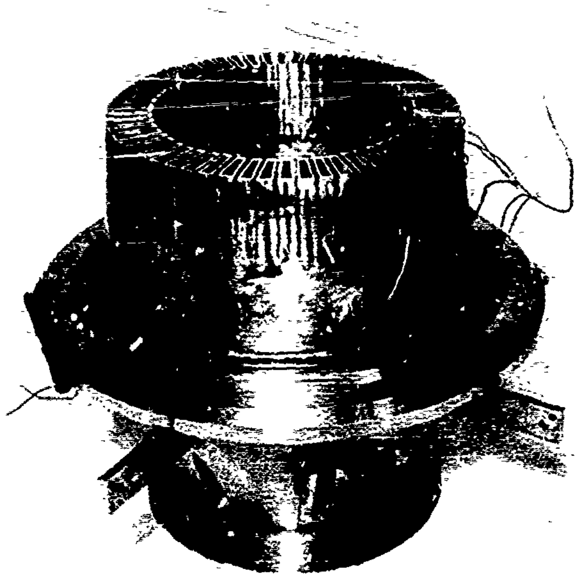
$$C_{Fg} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



HM-AP-36 NOZZLE

(ANNULUS ARRAY OF 60 SLOTS, AR 5.0)



Description:

The HM-AP-36 nozzle consists of an annulus arrangement of 60 equally spaced trapezoidal slots. Center-body ports provide secondary air to the central portion of the nozzle.

Number of elements: 60 trapezoidal slots

Area Ratio: 5.0

Flow Area: 13.2 Square Inches

Exit Cant Angle: 0 Degrees

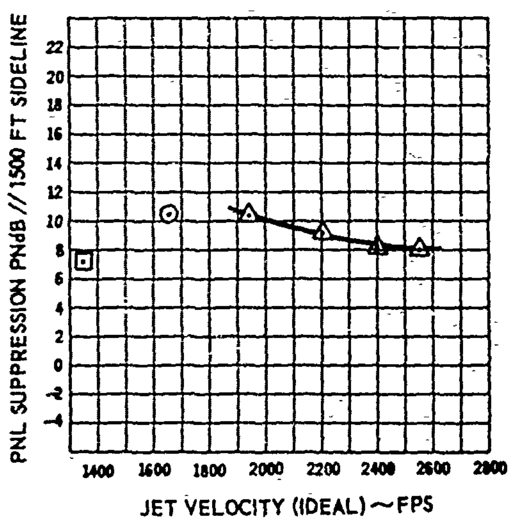
Slot Spacing Ratio: 2.0

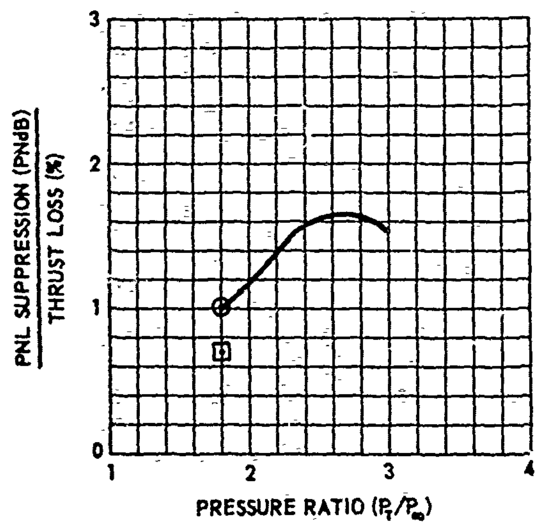
Slot Length (from nozzle base): 1.84 Inches

Flow Outer Diameter at Exit Plane: 9.166 Inches

Flow Inner Diameter at Exit Plane: 7.10 Inches

Maximum Design Gas Conditions: PR = 3.5, T_T = 1500°F



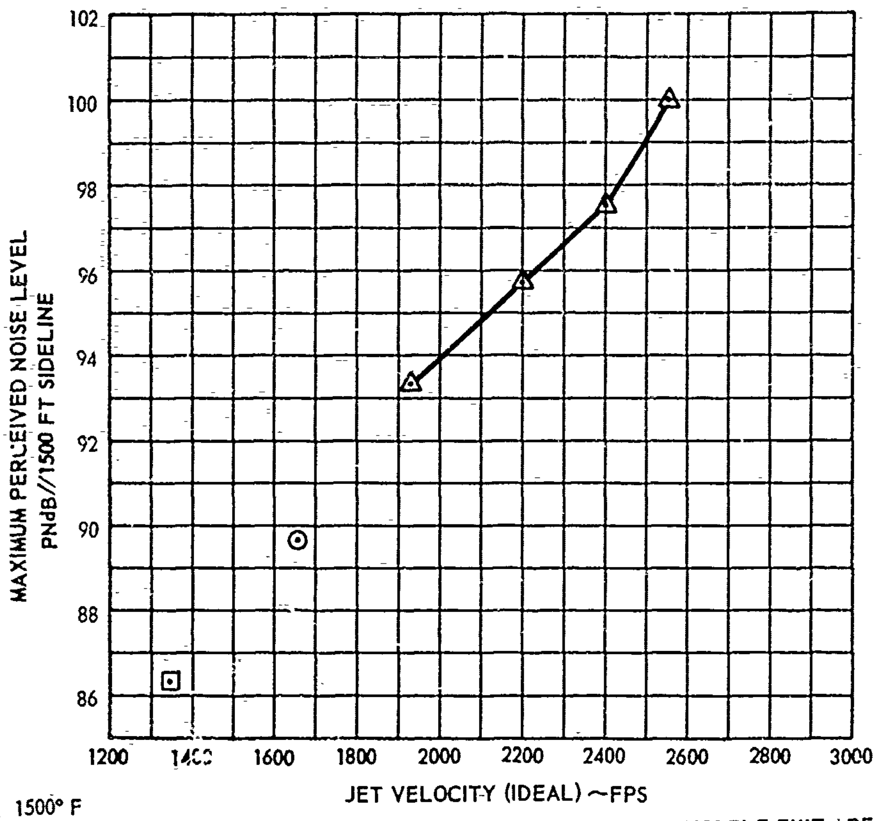


1500° F
1000° F
500° F

NOZZLE EXIT AREA (A_e): 5.9 FT²

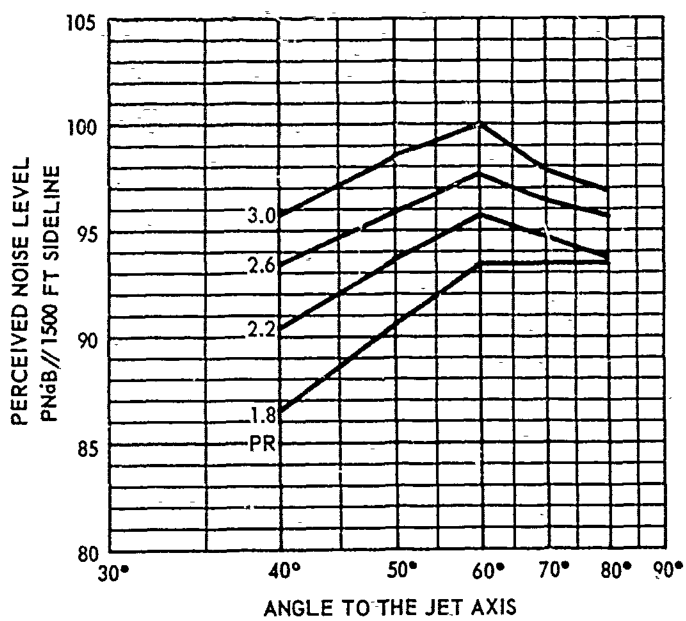
DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-36 NOZZLE
(ANNULUS ARRAY OF 60 SLOTS)
AR 5.0
SCALE FACTOR: 8:1



1500° F
1000° F
500° F

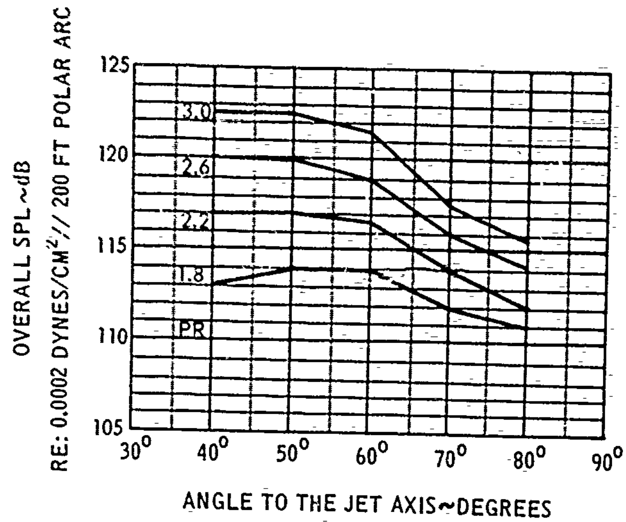
NOZZLE EXIT AREA (A_8): 5.9 FT^2



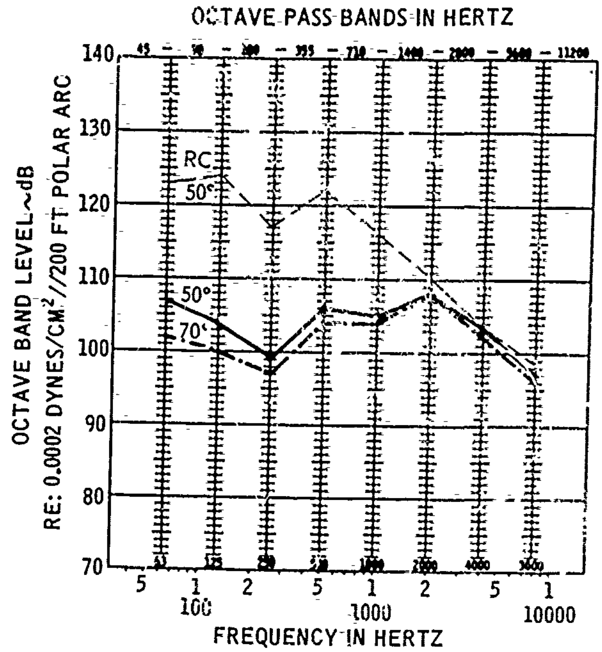
TOTAL TEMPERATURE (T_8): 1500° F

NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

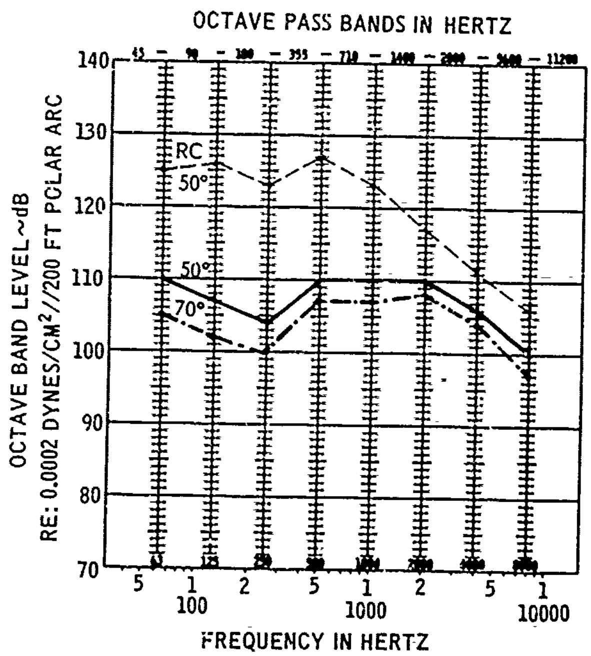


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8) : 5.9 FT.^{2}

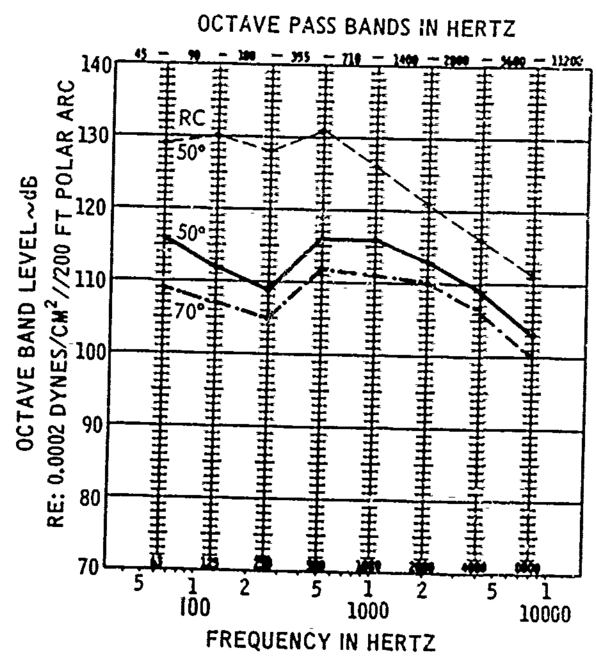


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT.^{2}

HM-AP-36 NOZZLE
(ANNULUS ARRAY OF 60 SLOTS)
AR 5.0
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT^2



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-36 NOZZLE

(Annulus Array of 60 Slots)

Remarks

The 60-slot annulus array (HM-AP-36) nozzle was compared with a simple annulus (HM-AP-12) nozzle. About 7 PNdB greater noise suppression was observed with the 60-slot annulus array. Reference D13. The 60-slot annulus nozzle provided 6 to 12 dB more suppression in the first four octave bands than the pure annulus nozzle. When ambient air was blocked (effective 0-inch length slots) from entering the slot array and with the nozzle center ventilation abrupted, there was a 1 to 2 PNdB improvement in PNL suppression.

One configuration of the 60-slot annulus array nozzle tested (HM-AP-36-A) had three concentric rings added which divides each slot into four parts. This increases the number of nozzle elements from 60 to 240. The HM-AP-36-A Nozzle configuration had an area ratio of 7.3. This nozzle attained a maximum noise suppression level of 18.8 PNdB (PR = 2.6 and T_T = 1500°F), however thrust loss was considerable, about 22%. See Reference D17.

Another 60-slot annulus array configuration investigated the effect of nozzle exit cant angle (-10°) and centerbody plugs on noise and performance. Reference D13. Four different plug lengths were tried. There was no significant difference observed in noise suppression when compared to the uncanted and unplugged HM-AP-36 Nozzle.

HM-AP-36 NOZZLE

Test Facility: Annex D
Microphone and nozzle height is 20 Inches

Date:

T_{amb}:

R.H.:

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
2621	1.8	540°F	1350 fps	HM-AP-36
2622	1.8	1000	1659	"
2623	1.8	1500	1923	"
2624	2.2	"	2202	"
2625	2.6	"	2402	"
2626	3.0	"	2555	"
2639	1.8	540°F	1350 fps	4.1 Inch Round Convergent Nozzle
2640	1.8	1000	1659	"
2641	1.8	1500	1923	"
2642	2.2	"	2202	"
2643	2.6	"	2402	"
2644	3.0	"	2555	"

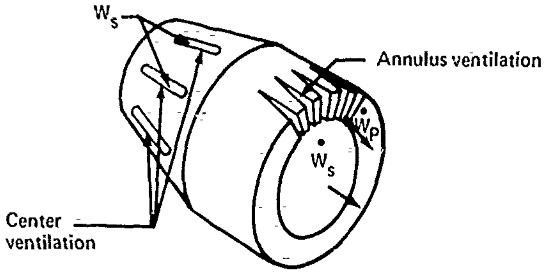
HM-AP-36 NOZZLE TEST DATA

OCTAVE BAND LEVEL–dB RE: 0.0002 DYNES/CM^2 // 25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
2621 L40	107.7	102.0	99.0	94.0	100.0	99.0	100.0	96.0	90.0
2621 L50	108.2	102.0	99.0	94.0	101.0	101.0	100.0	96.0	90.0
2621 L60	107.6	100.0	96.0	91.0	100.0	100.0	102.0	97.0	89.0
2621 L70	105.0	96.0	93.0	90.0	98.0	98.0	99.0	95.0	89.0
2621 L80	103.6	94.0	91.0	88.0	96.0	97.0	98.0	94.0	87.0
2622 L40	111.0	105.0	103.0	97.0	103.0	102.0	104.0	99.0	92.0
2622 L50	111.6	105.0	103.0	97.0	104.0	104.0	104.0	100.0	93.0
2622 L60	110.8	103.0	100.0	95.0	104.0	103.0	105.0	100.0	92.0
2622 L70	108.5	100.0	97.0	94.0	101.0	101.0	103.0	98.0	91.0
2622 L80	107.3	98.0	95.0	92.0	99.0	101.0	102.0	97.0	89.0
2623 L40	113.0	106.0	104.0	99.0	105.0	104.0	107.0	102.0	95.0
2623 L50	113.9	107.0	104.0	99.0	106.0	105.0	108.0	103.0	97.0
2623 L60	114.0	105.0	103.0	99.0	107.0	106.0	109.0	103.0	95.0
2623 L70	112.1	102.0	100.0	97.0	104.0	104.0	108.0	102.0	96.0
2623 L80	111.0	100.0	98.0	94.0	101.0	102.0	108.0	101.0	93.0
2624 L40	117.0	110.0	107.0	105.0	110.0	109.0	110.0	105.0	99.0
2624 L50	117.2	110.0	107.0	104.0	110.0	110.0	110.0	106.0	100.0
2624 L60	116.6	108.0	106.0	102.0	110.0	109.0	111.0	105.0	98.0
2624 L70	114.0	105.0	102.0	100.0	107.0	107.0	108.0	104.0	97.0
2624 L80	112.2	103.0	100.0	99.0	104.0	106.0	106.0	103.0	94.0
2625 L40	120.1	114.0	110.0	107.0	113.0	113.0	112.0	107.0	101.0
2625 L50	119.8	113.0	110.0	106.0	113.0	113.0	112.0	107.0	101.0
2625 L60	119.0	111.0	108.0	104.0	113.0	112.0	112.0	107.0	100.0
2625 L70	116.0	107.0	105.0	102.0	110.0	109.0	109.0	105.0	99.0
2625 L80	114.2	105.0	102.0	100.0	107.0	108.0	108.0	104.0	96.0
2626 L40	122.4	116.0	112.0	110.0	116.0	116.0	113.0	108.0	102.0
2626 L50	122.4	116.0	112.0	109.0	116.0	116.0	113.0	109.0	103.0
2626 L60	121.5	114.0	110.0	107.0	116.0	115.0	113.0	109.0	101.0
2626 L70	117.7	109.0	107.0	105.0	112.0	111.0	110.0	106.0	100.0
2626 L80	115.7	107.0	104.0	103.0	109.0	110.0	108.0	105.0	97.0
2639 L40	122.0	119.0	118.0	107.0	109.0	104.0	96.0	89.0	89.0
2639 L50	119.7	117.0	114.0	106.0	110.0	105.0	99.0	91.0	85.0
2639 L60	116.0	112.0	109.0	103.0	110.0	105.0	100.0	93.0	85.0
2639 L70	112.3	107.0	105.0	101.0	107.0	102.0	98.0	92.0	83.0
2639 L80	109.2	103.0	102.0	99.0	103.0	101.0	97.0	91.0	81.0
2640 L40	126.6	122.0	123.0	116.0	117.0	110.0	105.0	97.0	94.0
2640 L50	125.7	122.0	121.0	113.0	117.0	112.0	104.0	97.0	92.0
2640 L60	121.8	117.0	116.0	109.0	116.0	111.0	103.0	98.0	90.0
2640 L70	117.0	111.0	110.0	106.0	112.0	107.0	103.0	97.0	89.0
2640 L80	114.3	107.0	107.0	105.0	109.0	106.0	101.0	95.0	85.0
2641 L40	129.1	123.0	125.0	119.0	122.0	116.0	111.0	103.0	100.0
2641 L50	128.5	123.0	124.0	117.0	122.0	116.0	110.0	103.0	98.0
2641 L60	125.3	119.0	120.0	113.0	120.0	114.0	111.0	103.0	96.0
2641 L70	120.2	113.0	114.0	110.0	115.0	111.0	107.0	100.0	93.0
2641 L80	117.4	109.0	109.0	107.0	113.0	110.0	105.0	98.0	89.0
2642 L40	132.1	125.0	127.0	124.0	126.0	120.0	116.0	110.0	104.0
2642 L50	132.3	125.0	126.0	123.0	127.0	123.0	117.0	111.0	107.0
2642 L60	129.0	122.0	123.0	118.0	124.0	119.0	116.0	109.0	102.0
2642 L70	124.2	117.0	117.0	114.0	119.0	116.0	112.0	106.0	100.0
2642 L80	120.7	111.0	112.0	111.0	116.0	114.0	109.0	104.0	95.0
2643 L40	133.6	127.0	129.0	124.0	127.0	122.0	118.0	112.0	108.0
2643 L50	135.0	128.0	129.0	125.0	130.0	125.0	120.0	114.0	110.0
2643 L60	132.3	125.0	126.0	124.0	127.0	122.0	118.0	113.0	107.0
2643 L70	126.3	119.0	119.0	116.0	121.0	118.0	115.0	109.0	103.0
2643 L80	123.2	113.0	114.0	113.0	118.0	117.0	114.0	108.0	99.0
2644 L40	134.7	128.0	130.0	127.0	127.0	123.0	118.0	113.0	108.0
2644 L50	136.3	129.0	130.0	128.0	131.0	126.0	121.0	116.0	111.0
2644 L60	133.9	126.0	127.0	124.0	129.0	125.0	121.0	116.0	110.0
2644 L70	128.5	120.0	120.0	119.0	124.0	120.0	117.0	112.0	106.0
2644 L80	125.8	116.0	115.0	116.0	120.0	120.0	117.0	111.0	103.0

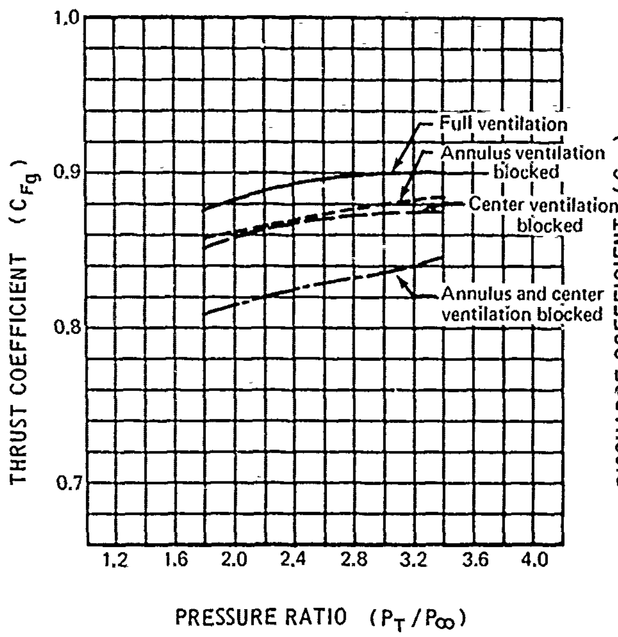
NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

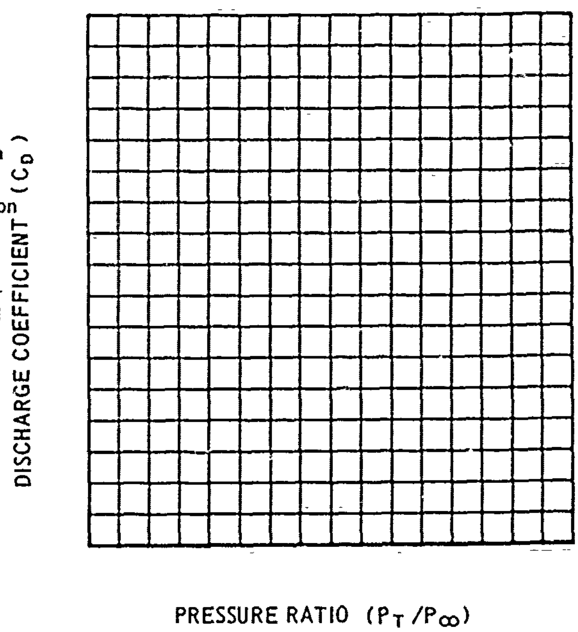
HM-AP-36

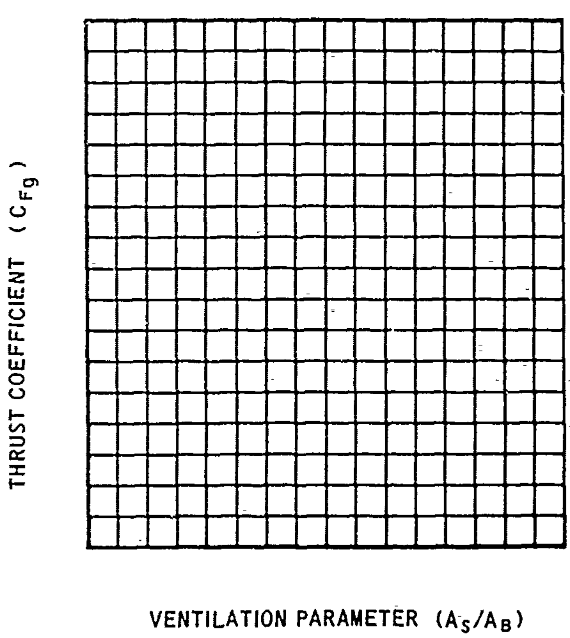


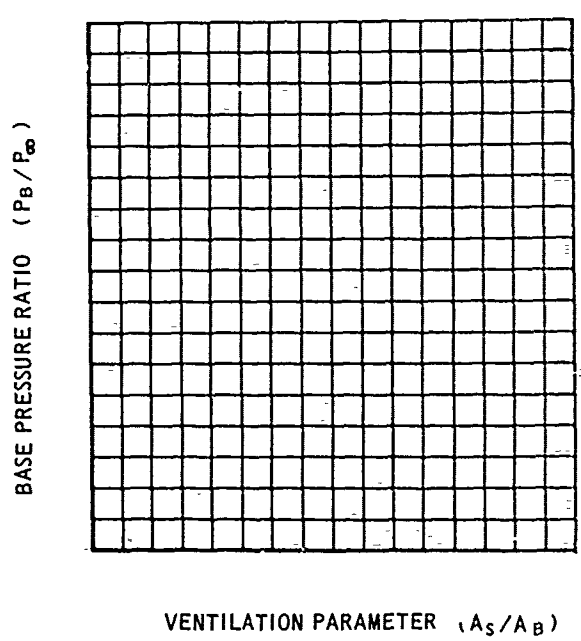
$$C_{F_g} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$

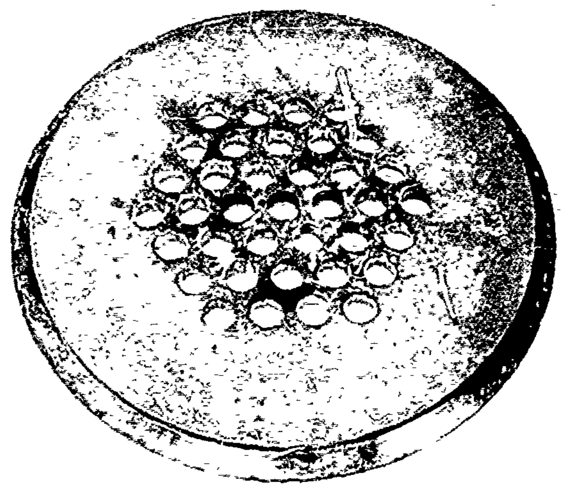








HM-AP-37 NOZZLE
(37 TUBE HEXAGONAL ARRAY AR4.65)



BASE PLATE WITH TUBES REMOVED

Description:

The HM-AP-37 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have round convergent terminations. The tubes were inserted into a 17-inch diameter baseplate and were removable.

Number of Elements: 37 tubes with round convergent ends

Area Ratio: 4.65

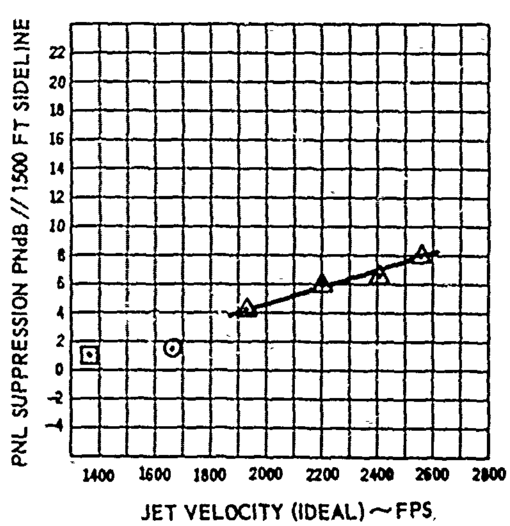
Flow Area: 13.2 Square Inches

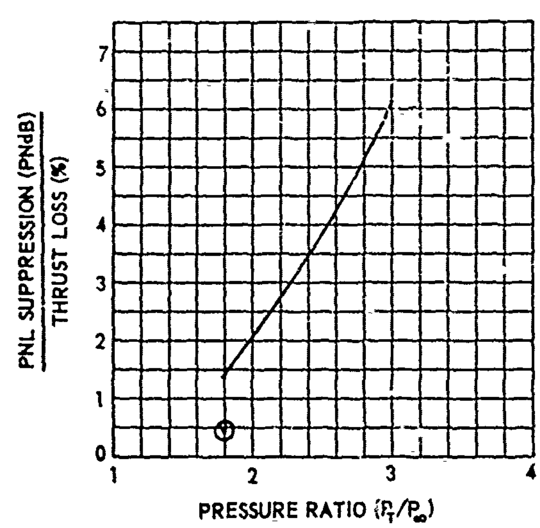
Exit Cant Angle: 0 Degrees

Length of Tubes: 7 Inches

Tube Exit Diameter: 0.674 Inches

Material: 321 CRES





1500° F

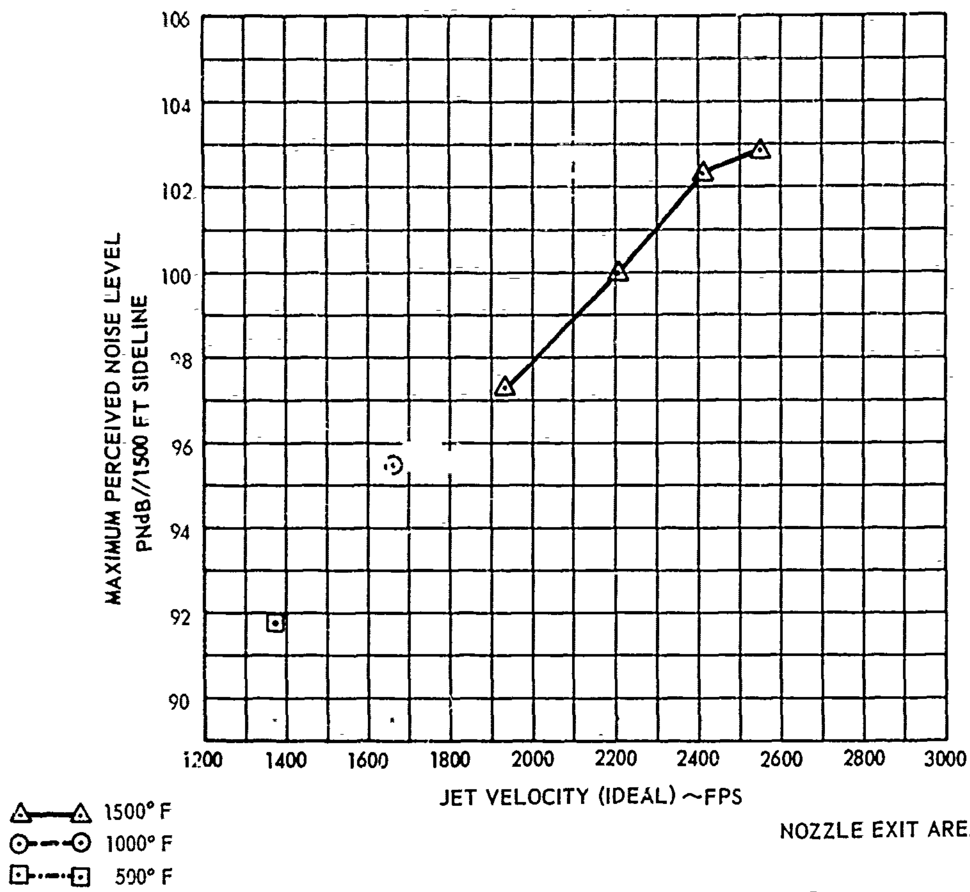
1000° F

500° F

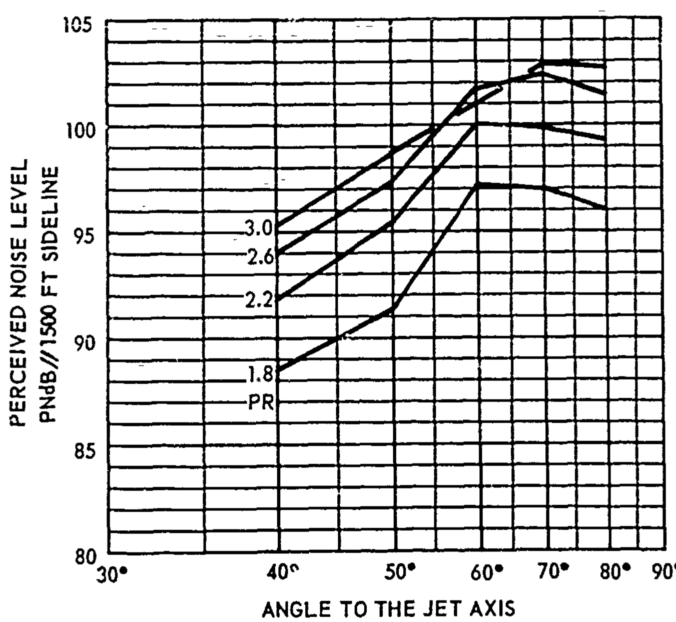
NOZZLE EXIT AREA (A_J): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-37 NOZZLE
(37 TUBE HEXAGONAL ARRAY)
AR 4.65
SCALE FACTOR: 8:1



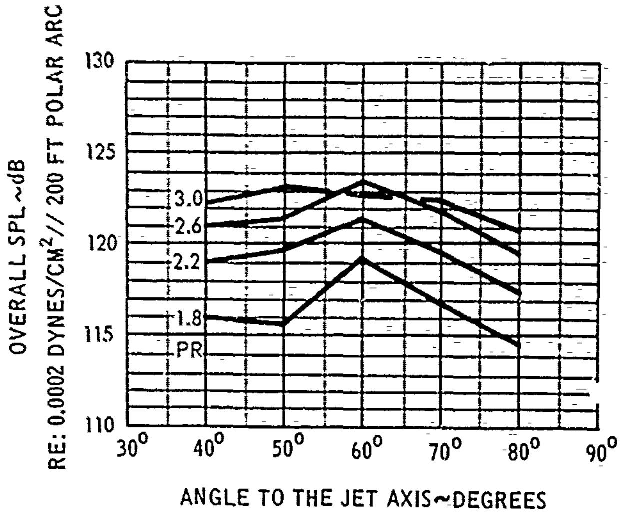
NOZZLE EXIT AREA (A_8): 5.9 FT^2



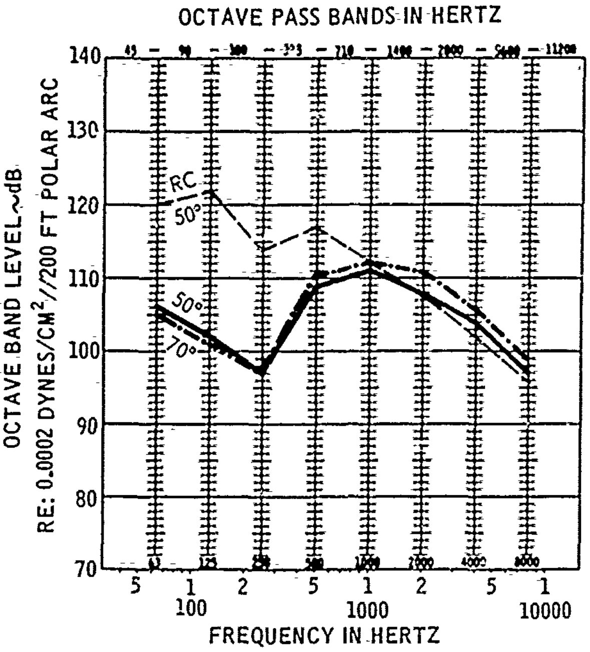
TOTAL TEMPERATURE (T_8): 1500° F

NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

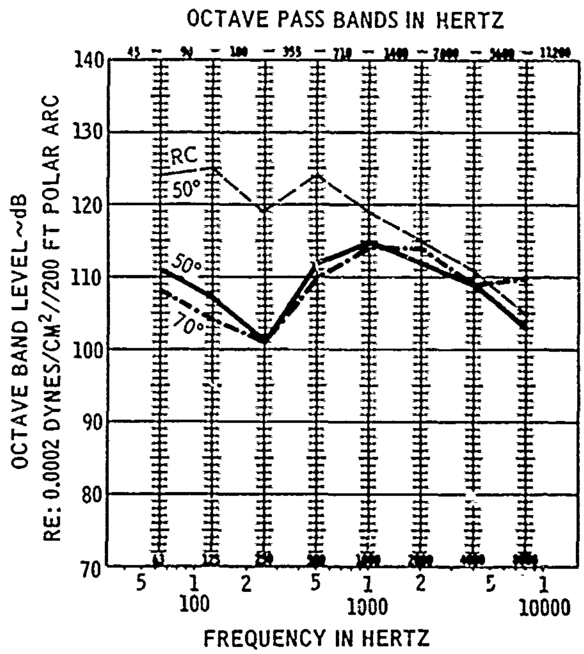


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

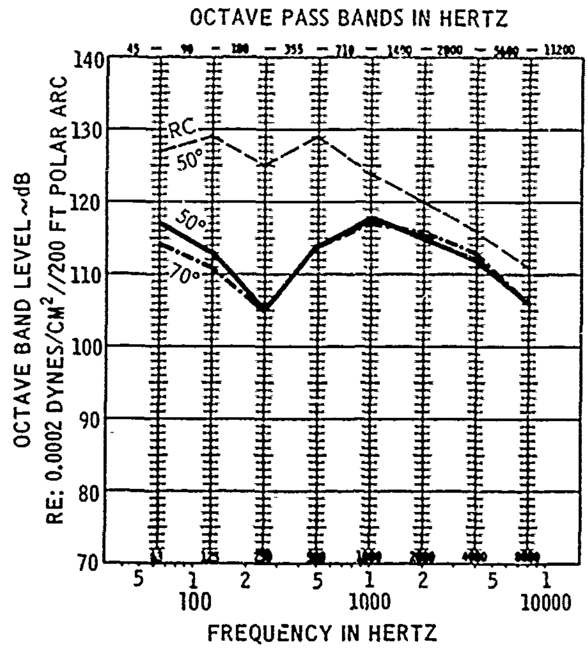


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

HM-AP-37 NOZZLE
(37 TUBE HEXAGONAL ARRAY)
AR 4.65
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2255 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-37 NOZZLE

(37 Tube Hexagonal Array, AR = 4.65)

Remarks

The HM-AP-37 Nozzle was part of a parametric study to study the effect of area ratio on noise suppression. Area ratios of 3.33, 4.0, 4.65, 5.2 and 8.0 (HM-AP-43, HM-AP-39, HM-AP-37, HM-AP-44 and HM-AP-38) were tested. At pressure ratios $\leq$ 3.0 and T_T = 1500°F better PNL suppression could be obtained with area ratios of 3.33 or 4.0. See Reference D19.

A retest of the HM-AP-37 Nozzle, Reference D20, indicated substantial agreement in OASPL and PNL suppression. However, a 4 to 9 dB difference in first and second octave band levels was noted.

HM-AP-37 NOZZLE

Test Facility: Annex D
Microphone and Nozzle Height is 20 Inches

Date: ca. March 1968

T_{amb}: not available

R.H.: not available

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
2855	1.8	540°F	1370 fps	HM-AP-37
2856	1.8	1000	1659	"
2857	1.8	1500	1923	"
2858	2.2	"	2202	"
2859	2.6	"	2402	"
2860	3.0	"	2555	"

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
2849	1.8	540°F	1370 fps	4.1 Inch Round Convergent Nozzle
2850	1.8	1000	1659	"
2851	1.8	1500	1923	"
2852	2.2	"	2202	"
2853	2.6	"	2402	"
2854	3.0	"	2555	"

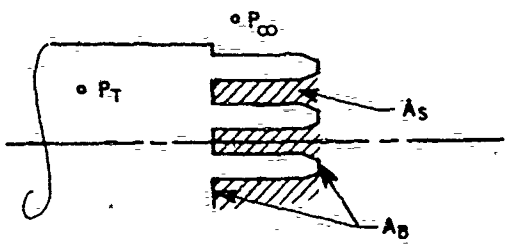
HM-AP-37 NOZZLE TEST DATA

OCTAVE BAND LEVEL ~ dB RE: 0.0002 DYNES/CM^2// 25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
2855 L40	111.8	106.0	100.0	93.0	106.0	105.0	103.0	98.0	89.0
2855 L50	113.0	107.0	101.0	95.0	107.0	107.0	103.0	100.0	93.0
2855 L60	113.8	107.0	101.0	96.0	107.0	108.0	106.0	102.0	93.0
2855 L70	110.2	103.0	97.0	93.0	102.0	104.0	104.0	100.0	92.0
2855 L80	108.2	100.0	94.0	91.0	101.0	101.0	102.0	100.0	93.0
2856 L40	115.3	109.0	104.0	95.0	108.0	110.0	107.0	102.0	93.0
2856 L50	115.5	109.0	105.0	97.0	108.0	110.0	107.0	103.0	95.0
2856 L60	117.3	109.0	104.0	99.0	111.0	112.0	110.0	105.0	96.0
2856 L70	114.0	106.0	102.0	95.0	106.0	108.0	108.0	103.0	96.0
2856 L80	111.7	104.0	98.0	92.0	103.0	105.0	106.0	103.0	95.0
2857 L40	115.9	106.0	102.0	96.0	108.0	112.0	109.0	104.0	96.0
2857 L50	115.6	106.0	102.0	97.0	109.0	111.0	108.0	104.0	97.0
2857 L60	119.2	108.0	103.0	101.0	113.0	115.0	112.0	107.0	99.0
2857 L70	116.8	105.0	101.0	97.0	110.0	112.0	111.0	106.0	99.0
2857 L80	114.5	102.0	98.0	94.0	106.0	109.0	109.0	107.0	100.0
2858 L40	119.0	110.0	105.0	98.0	111.0	114.0	113.0	108.0	100.0
2858 L50	119.6	111.0	107.0	101.0	112.0	115.0	112.0	109.0	103.0
2858 L60	121.5	112.0	107.0	104.0	114.0	117.0	115.0	110.0	103.0
2858 L70	119.5	108.0	104.0	101.0	110.0	114.0	114.0	109.0	110.0
2858 L80	117.4	105.0	101.0	98.0	107.0	111.0	113.0	110.0	103.0
2859 L40	121.0	112.0	108.0	100.0	113.0	116.0	115.0	110.0	102.0
2859 L50	121.3	114.0	109.0	102.0	113.0	116.0	114.0	111.0	105.0
2859 L60	123.6	115.0	110.0	105.0	116.0	119.0	116.0	113.0	105.0
2859 L70	121.9	111.0	108.0	102.0	114.0	117.0	116.0	112.0	105.0
2859 L80	119.5	108.0	105.0	100.0	109.0	113.0	115.0	112.0	106.0
2860 L40	122.3	115.0	111.0	103.0	114.0	117.0	115.0	111.0	104.0
2860 L50	123.3	117.0	113.0	105.0	114.0	118.0	115.0	112.0	106.0
2860 L60	122.8	116.0	112.0	105.0	115.0	117.0	115.0	112.0	104.0
2860 L70	122.5	114.0	111.0	105.0	114.0	117.0	116.0	113.0	106.0
2860 L80	120.9	112.0	108.0	101.0	110.0	114.0	116.0	113.0	106.0
2849 L40	117.9	114.0	114.0	103.0	108.0	103.0	99.0	92.0	86.0
2849 L50	115.8	111.0	110.0	104.0	105.0	105.0	100.0	95.0	88.0
2849 L60	115.2	111.0	107.0	103.0	109.0	106.0	101.0	96.0	88.0
2849 L70	111.1	103.0	103.0	100.0	106.0	104.0	100.0	96.0	89.0
2849 L80	109.8	101.0	102.0	99.0	104.0	102.0	101.0	97.0	91.0
2850 L40	123.7	119.0	120.0	110.0	115.0	109.0	105.0	99.0	92.0
2850 L50	121.4	116.0	117.0	110.0	114.0	110.0	105.0	100.0	93.0
2850 L60	119.1	114.0	112.0	107.0	113.0	110.0	106.0	101.0	92.0
2850 L70	116.1	107.0	108.0	105.0	111.0	109.0	106.0	101.0	93.0
2850 L80	113.4	104.0	105.0	102.0	108.0	106.0	104.0	101.0	96.0
2851 L40	126.1	121.0	122.0	113.0	119.0	113.0	108.0	102.0	96.0
2851 L50	125.5	120.0	122.0	114.0	117.0	112.0	108.0	102.0	96.0
2851 L60	123.7	118.0	118.0	113.0	117.0	114.0	109.0	105.0	97.0
2851 L70	119.3	112.0	112.0	108.0	114.0	111.0	108.0	103.0	96.0
2851 L80	116.6	108.0	109.0	105.0	111.0	109.0	107.0	104.0	98.0
2852 L40	130.1	125.0	125.0	118.0	123.0	119.0	115.0	110.0	103.0
2852 L50	130.1	124.0	125.0	119.0	124.0	119.0	115.0	111.0	105.0
2852 L60	127.9	121.0	122.0	117.0	122.0	119.0	115.0	111.0	103.0
2852 L70	123.8	115.0	116.0	112.0	119.0	116.0	114.0	108.0	102.0
2852 L80	120.5	111.0	112.0	109.0	115.0	113.0	112.0	108.0	102.0
2853 L40	132.6	127.0	128.0	120.0	126.0	121.0	118.0	112.0	107.0
2853 L50	132.6	126.0	127.0	122.0	127.0	122.0	118.0	115.0	110.0
2853 L60	130.6	123.0	124.0	121.0	125.0	122.0	118.0	114.0	107.0
2853 L70	125.9	117.0	117.0	114.0	121.0	119.0	116.0	111.0	105.0
2853 L80	123.1	112.0	114.0	112.0	118.0	116.0	114.0	112.0	107.0
2854 L40	134.0	129.0	130.0	121.0	126.0	121.0	117.0	113.0	107.0
2854 L50	134.5	127.0	129.0	125.0	129.0	124.0	120.0	116.0	111.0
2854 L60	132.4	124.0	126.0	123.0	127.0	124.0	120.0	116.0	110.0
2854 L70	128.1	118.0	120.0	117.0	123.0	121.0	119.0	114.0	108.0
2854 L80	124.9	114.0	115.0	114.0	119.0	118.0	117.0	114.0	105.0

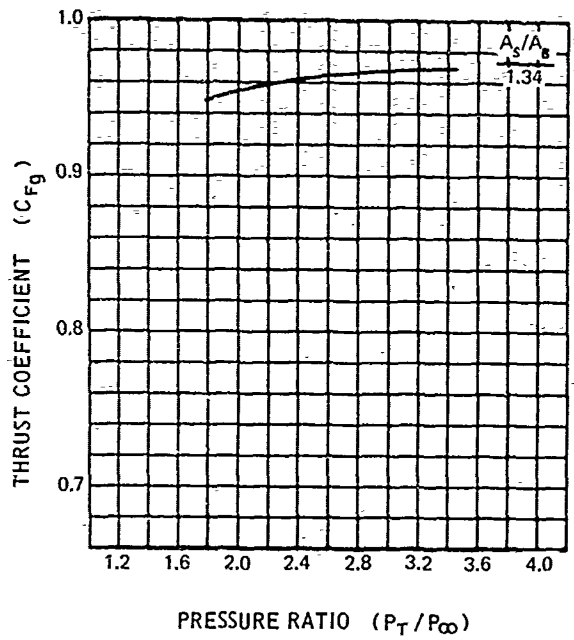
NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

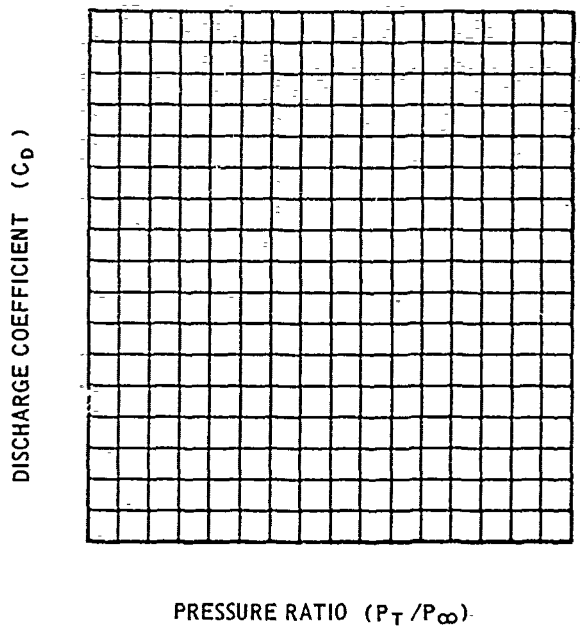
HM-AP-37

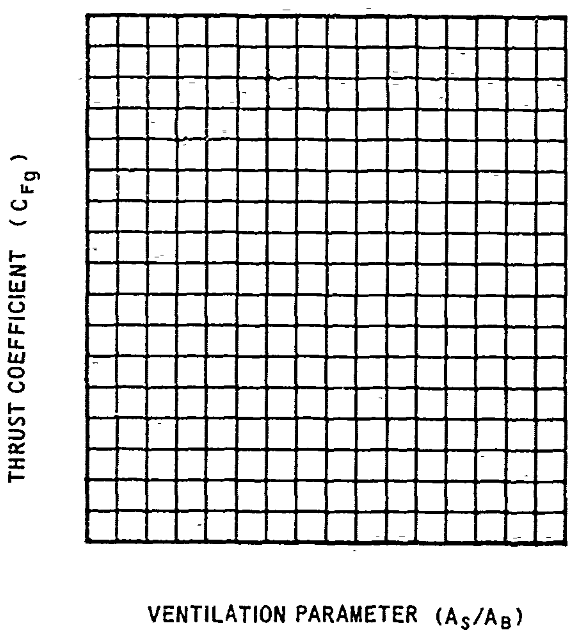


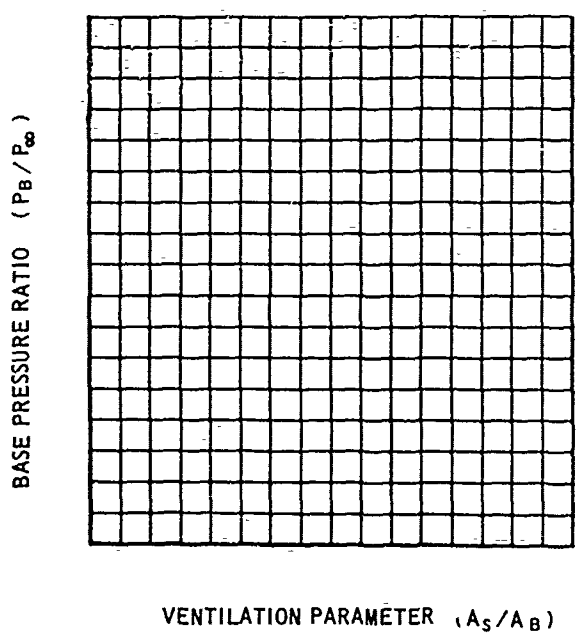
$$C_{Fg} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



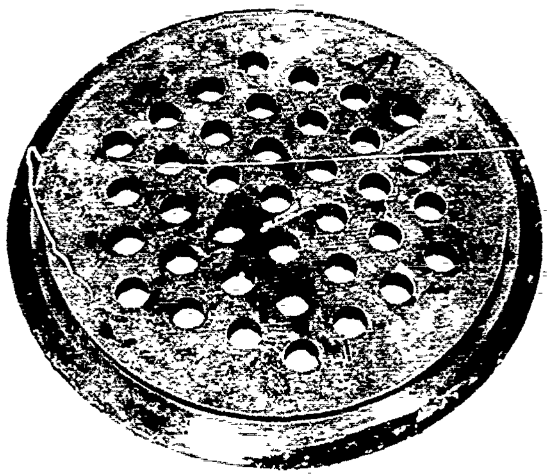






HM-AP-38 NOZZLE

(37 TUBE HEXAGONAL ARRAY, AR 8.0)



BASE PLATE WITH TUBES REMOVED

Description:

The HM-AP-38 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have round convergent terminations. The tubes were inserted into a 17-inch diameter baseplate and were removeable.

Number of Elements: 37 tubes with round convergent ends

Area Ratio: 8.0

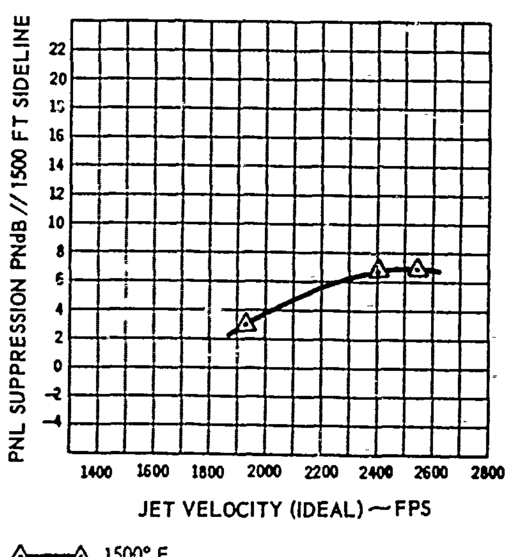
Flow Area: 13.2 square inches

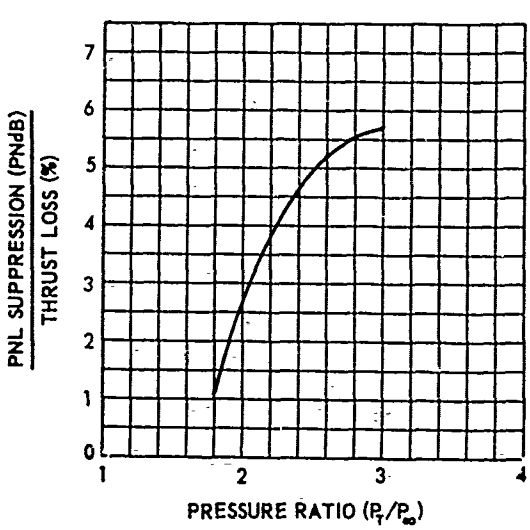
Exit Cant Angle: 0 degrees

Length of Tubes: 7 inches

Tube Exit Diameter: 0.674 inches

Material: 321 CRES

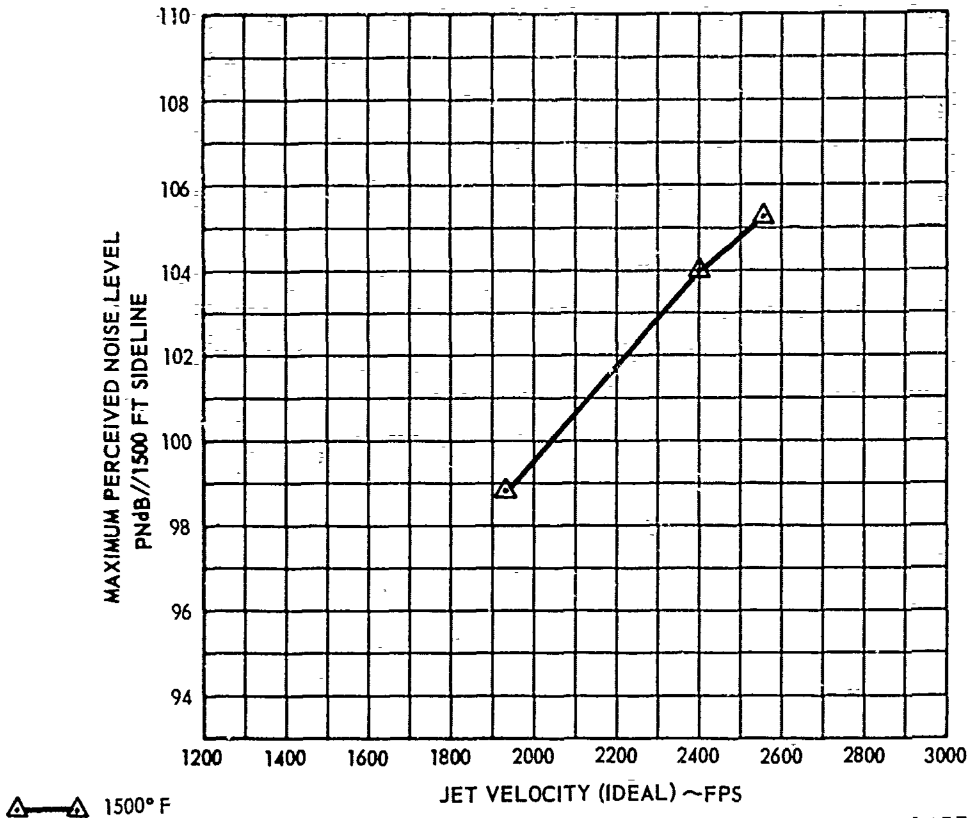




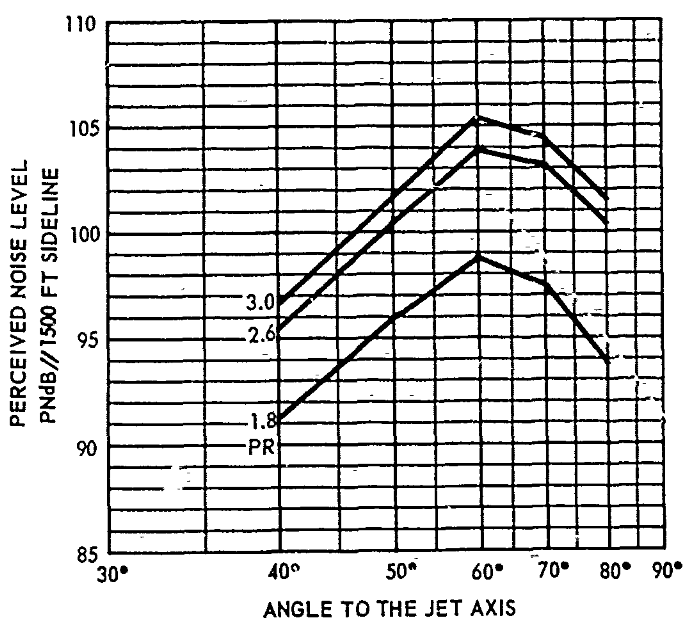
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-38 NOZZLE
(37 TUBE HEXAGONAL ARRAY)
AR 8.0
SCALE FACTOR: 8:1



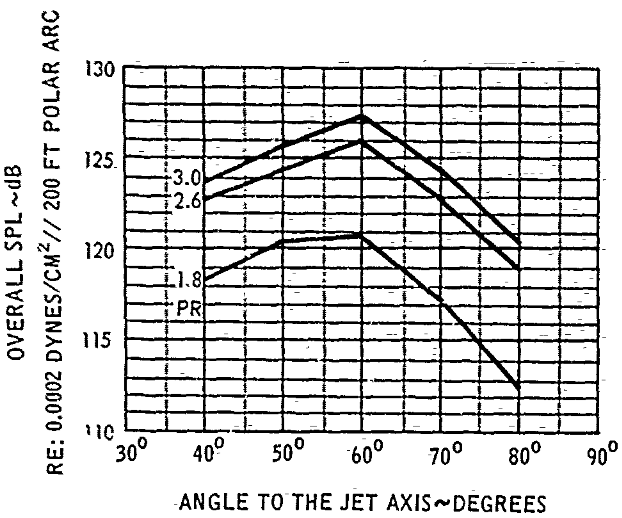
NOZZLE EXIT AREA (A_8): 5.9 FT^2



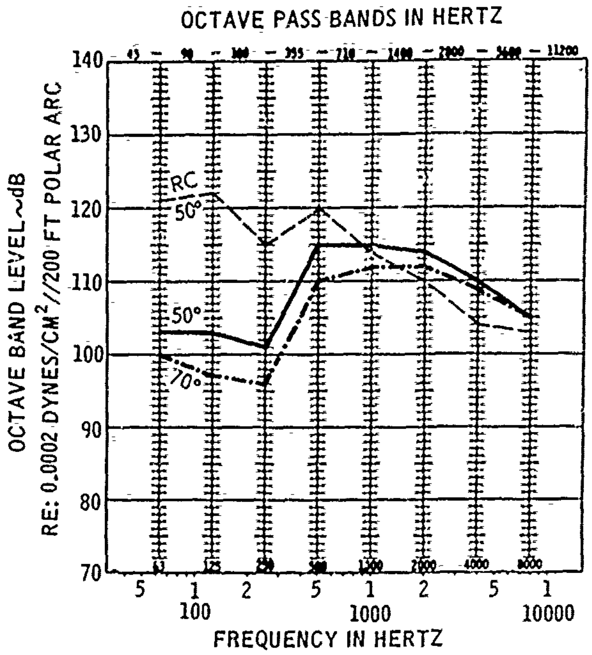
TOTAL TEMPERATURE (T_8): 1500° F

NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

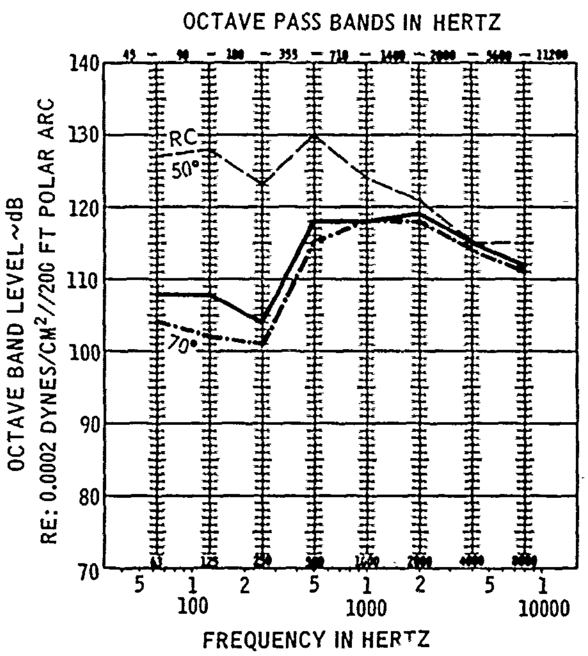


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT^2

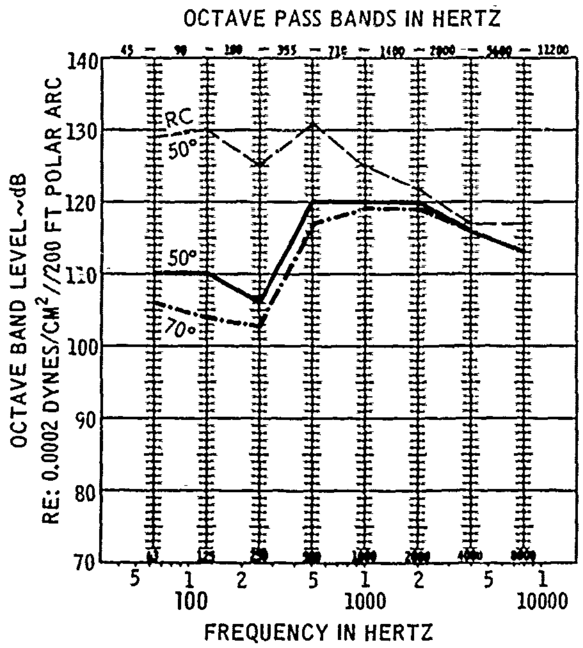


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT^2

HM-AP-38 NOZZLE
(37 TUBE HEXAGONAL ARRAY)
AR 8.0
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2402 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT^2



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-38 NOZZLE

(37 Tube Hexagonal Array, AR = 8.0)

Remarks

The HM-AP-38 nozzle had the largest area ratio of a 37 tube nozzle parametric study where area ratios varied from 3.33 to 8.0. Very good jet merging noise suppression was evident in the low frequency portion of the spectrum. This advantage was off-set by the relative high levels in the high frequency portion of the spectrum attributed to pre-merging jet mixing noise. See Reference D19.

HM-AP-38

Test Facility: Annex D

Date:

T_{amb}:

R. H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H1257	1.8	1500°F	1923 fps	HM-AP-38
H1258	2.6	"	2402	"
H1259	3.0	"	2555	"
H1227	1.8	1500°F	1923 fps	4.1 Inch Round Convergent Nozzle
H1228	2.6	"	2402	"
H1229	3.0	"	2555	"

Measured acoustic data is included in Reference D2.

NOZZLE TEST DATA

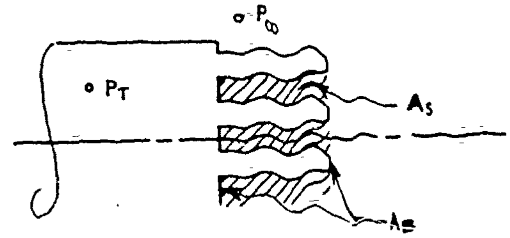
OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM²/25 FT

HM-AP-38

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H1257L40	118.3	102.0	102.0	100.0	113.0	113.0	112.0	108.0	103.0
H1257L50	120.3	103.0	103.0	101.0	115.0	115.0	114.0	110.0	105.0
H1257L60	120.9	102.0	101.0	100.0	114.0	117.0	115.0	110.0	105.0
H1257L70	117.4	100.0	97.0	96.0	110.0	112.0	112.0	109.0	105.0
H1257L80	112.6	97.0	94.0	94.0	105.0	107.0	107.0	105.0	100.0
H1258L40	122.8	106.0	105.0	104.0	117.0	117.0	117.0	113.0	110.0
H1258L50	124.3	108.0	108.0	104.0	118.0	118.0	119.0	115.0	112.0
H1258L60	126.0	107.0	106.0	104.0	119.0	122.0	120.0	116.0	111.0
M1258L70	123.0	104.0	102.0	101.0	115.0	118.0	118.0	114.0	111.0
H1258L80	119.0	101.0	99.0	98.0	110.0	113.0	114.0	112.0	107.0
H1259L40	123.8	108.0	107.0	106.0	118.9	118.0	110.0	114.0	111.0
H1259L50	125.8	110.0	110.0	106.0	120.0	120.0	120.0	116.0	111.0
H1259L60	127.3	109.0	108.0	106.0	121.0	123.0	121.0	117.0	112.0
H1259L70	124.4	106.0	104.0	103.0	117.0	119.0	119.0	116.0	113.0
H1259L80	120.1	103.0	101.0	100.0	112.0	114.0	115.0	113.0	108.0
H1227L40	127.9	122.0	124.0	116.0	121.0	114.0	110.0	104.0	103.0
H1227L50	126.6	121.0	122.0	115.0	120.0	114.0	110.0	104.0	103.0
H1227L60	122.9	116.0	116.0	111.0	118.0	114.0	110.0	105.0	100.0
H1227L70	120.8	112.0	113.0	108.0	117.0	112.0	109.0	104.0	101.0
H1227L80	116.3	108.0	108.0	105.0	112.0	108.0	105.0	101.0	96.0
H1228L40	134.4	128.0	130.0	123.0	128.0	122.0	119.0	114.0	113.0
H1228L50	134.4	127.0	128.0	123.0	130.0	124.0	121.0	115.0	115.0
H1228L60	130.2	121.0	123.0	119.0	126.0	122.0	118.0	114.0	109.0
H1228L70	127.9	117.0	119.0	116.0	124.0	120.0	118.0	113.0	110.0
H1228L80	123.1	113.0	113.0	111.0	119.0	116.0	113.0	110.0	105.0
H1229L40	135.4	130.0	131.0	124.0	128.0	123.0	119.0	114.0	113.0
H1229L50	136.0	129.0	130.0	125.0	131.0	125.0	122.0	117.0	117.0
H1229L60	132.1	123.0	124.0	121.0	128.0	124.0	120.0	116.0	112.0
H1229L70	129.8	119.0	120.0	118.0	126.0	122.0	120.0	116.0	113.0
H1229L80	125.6	115.0	115.0	114.0	121.0	119.0	115.0	113.0	108.0

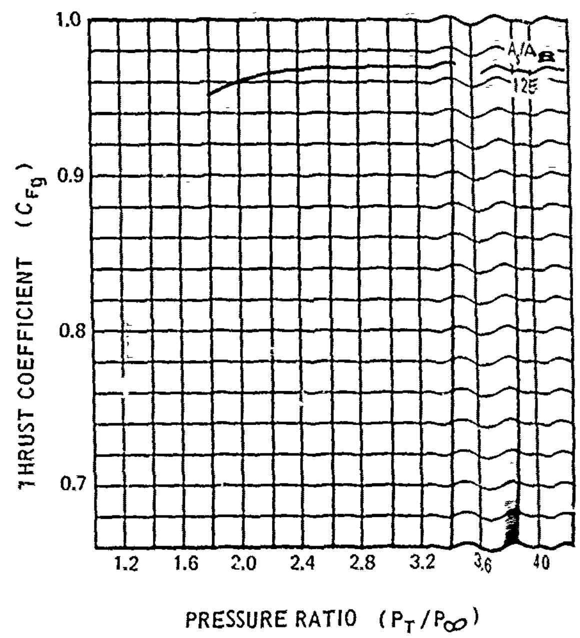
NOTE: DATA INCLUDES GROUND RELECTION INTERFERENCE

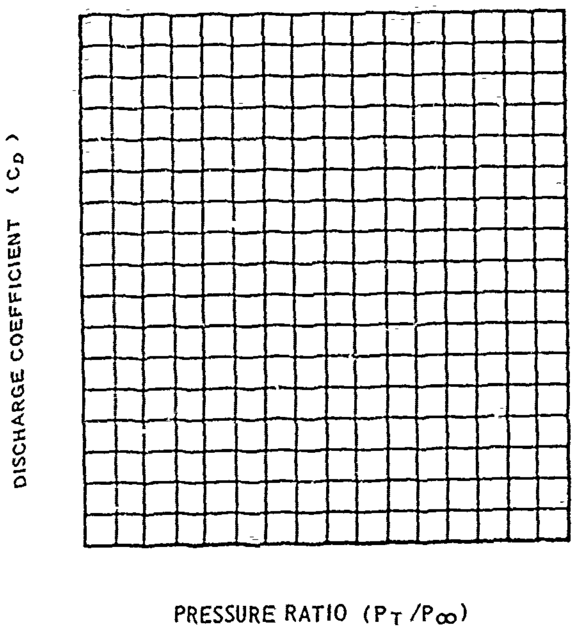
HM-AP-38

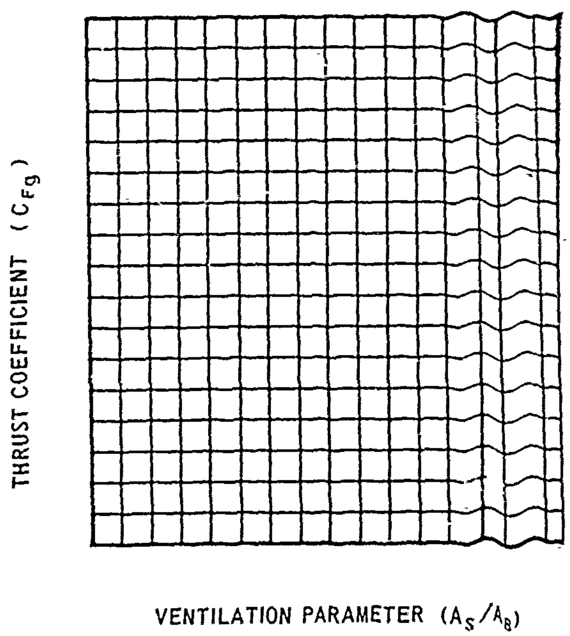


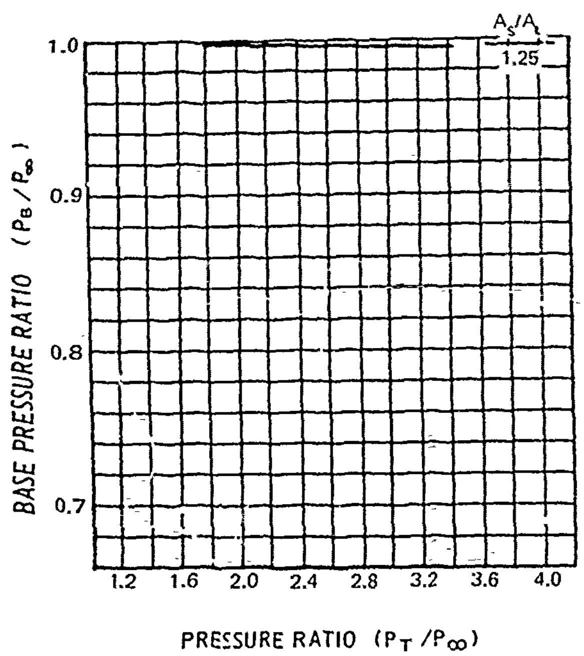
$$C_{Fg} = \frac{(\text{THRUST-DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$









HM-AP-39 NOZZLE

(37 TUBE, HEXAGONAL ARRAY, AR 4.0)

Description:

The HM-AP-39 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have round convergent terminations. The tubes were inserted into a 17-inch diameter baseplate and were removable.

Number of Elements: 37 tubes with round convergent ends

Area Ratio: 4.0

Flow Area: 13.2 square inches

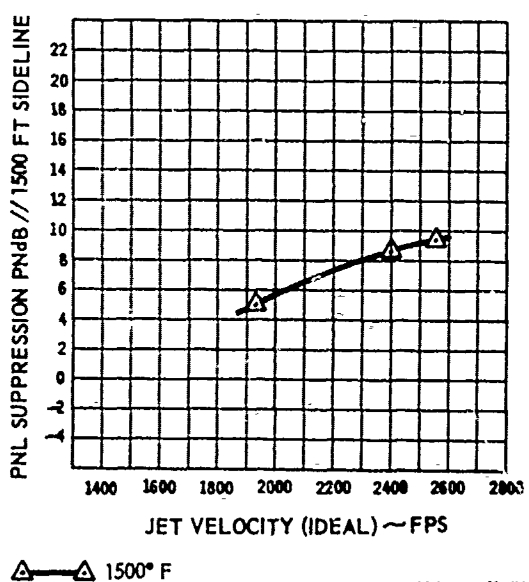
Exit Cant Angle: 0 degrees

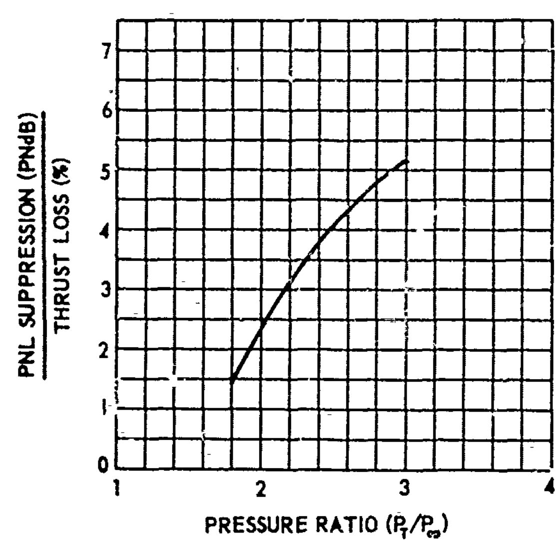
Length of Tubes: 7 inches

Tube Exit Diameter: 0.674 inches

Material: 321 CRES

NO PICTURE AVAILABLE

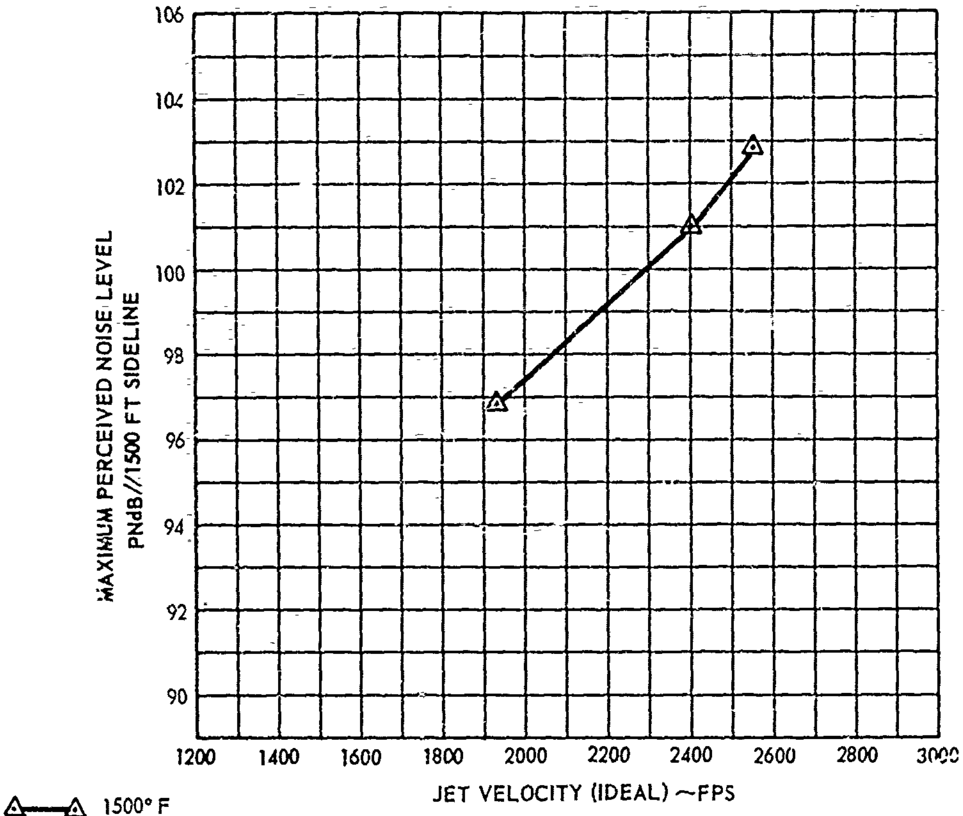




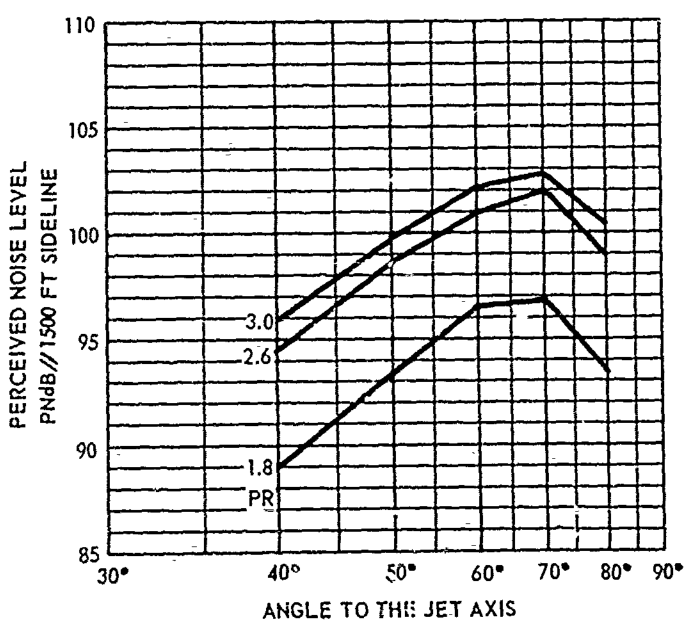
NOZZLE EXIT AREA (A_e): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-39 NOZZLE
(37 TUBE HEXAGONAL ARRAY)
AR 4.0
SCALE FACTOR: 8:1



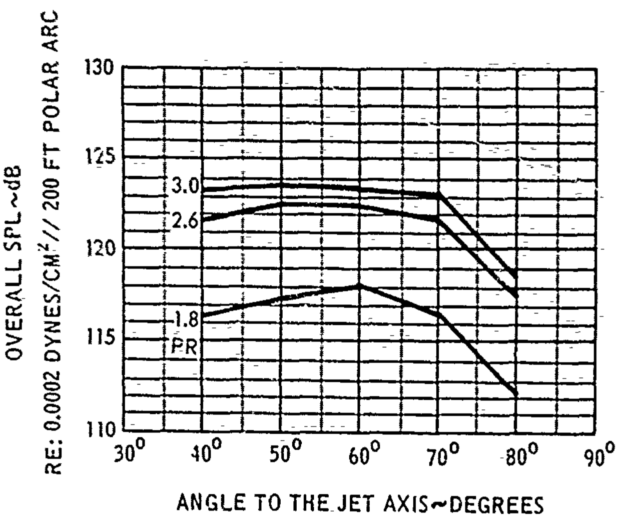
NOZZLE EXIT AREA (A_8): 5.9 FT^2



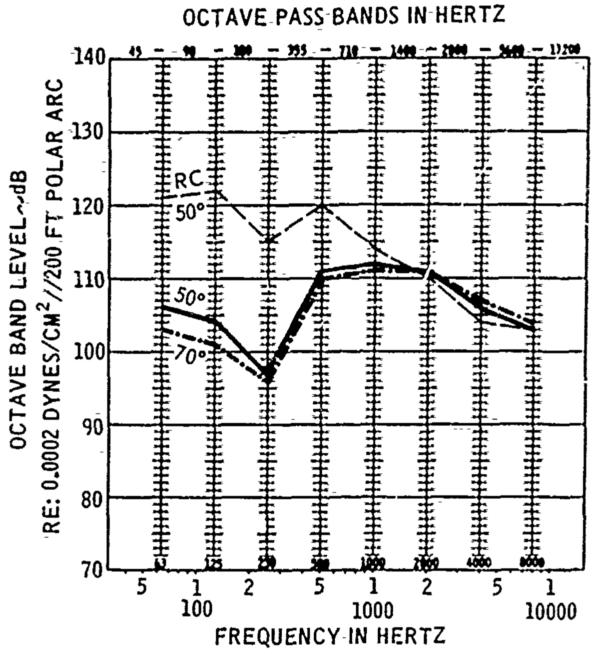
TOTAL TEMPERATURE (T_8): 1500° F

NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

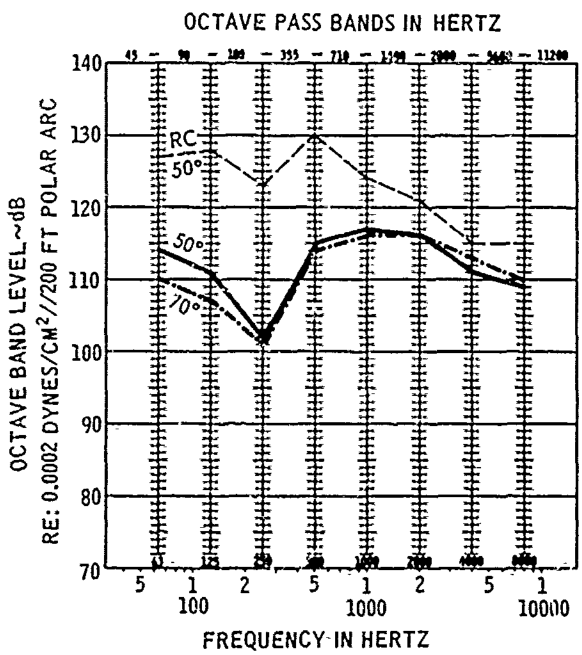


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

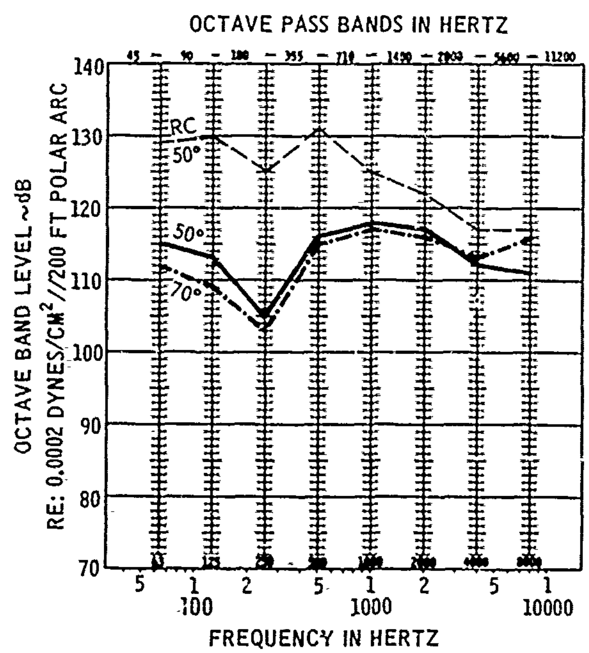


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

HM-AP-39 NOZZLE
(37 TUBE HEXAGONAL ARRAY)
AR 4.0
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2402 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-39 NOZZLE

(37 Tube Hexagonal Array, AR = 4.0)

Remarks

The HM-AP-39 nozzle was tested with several different tube lengths (Ref. D19). Nozzle configurations with effective tube lengths of 7 inches, 5 inches, 3 inches or 1 inch showed essentially no differences in jet noise characteristics.

HM-AP-39

Test Facility: Annex D
Nozzle and Microphone Height is 20 Inches

Date:

T_{amb}: not available

R.H.: not available

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H1236	1.8	1500°F	1923 fps	HM-AP-39
H1237	2.6	"	2402	"
H1238	3.0	"	2555	"
H1227	1.8	1500°F	1923	4.1-Inch Round Convergent Nozzle
H1228	2.6	"	2402	"
H1229	3.0	"	2555	"

Measured acoustic data is included in Reference D2.

NOZZLE TEST DATA

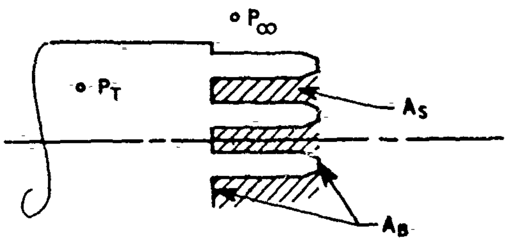
OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-39

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H1236 L40	116.4	105.0	103.0	96.0	109.0	112.0	110.0	105.0	102.0
H1236 L50	117.3	106.0	104.0	97.0	111.0	112.0	111.0	106.0	103.0
H1236 L60	118.1	105.0	102.0	99.0	112.0	113.0	112.0	108.0	102.0
H1236 L70	116.7	103.0	101.0	96.0	110.0	111.0	111.0	107.0	104.0
H1236 L80	112.1	100.0	98.0	93.0	104.0	106.0	106.0	105.0	99.0
H1237 L40	121.6	113.0	109.0	102.0	114.0	116.0	115.0	111.0	107.0
H1237 L50	122.6	114.0	111.0	102.0	115.0	117.0	116.0	111.0	109.0
H1237 L60	122.5	112.0	109.0	103.0	116.0	117.0	116.0	112.0	107.0
H1237 L70	121.8	110.0	107.0	101.0	114.0	116.0	116.0	113.0	110.0
H1237 L80	107.7	97.0	94.0	88.0	98.0	101.0	102.0	101.0	95.0
H1238 L40	123.3	116.0	112.0	104.0	115.0	118.0	116.0	111.0	108.0
H1238 L50	123.7	115.0	113.0	104.0	116.0	118.0	117.0	112.0	111.0
H1238 L60	123.5	113.0	111.0	105.0	117.0	118.0	117.0	113.0	108.0
H1238 L70	123.2	112.0	109.0	103.0	115.0	117.0	116.0	113.0	116.0
H1238 L80	118.5	108.0	105.0	100.0	109.0	112.0	113.0	111.0	106.0
H1227 L40	127.9	122.0	124.0	116.0	121.0	114.0	110.0	104.0	103.0
H1227 L50	126.6	121.0	122.0	115.0	120.0	114.0	110.0	104.0	103.0
H1227 L60	122.9	116.0	116.0	111.0	118.0	114.0	110.0	105.0	100.0
H1227 L70	120.8	112.0	113.0	108.0	117.0	112.0	109.0	104.0	101.0
H1227 L80	116.3	108.0	108.0	105.0	112.0	108.0	105.0	101.0	96.0
H1228 L40	134.4	128.0	130.0	123.0	128.0	122.0	119.0	114.0	113.0
H1228 L50	134.4	127.0	128.0	123.0	130.0	124.0	121.0	115.0	115.0
H1228 L60	130.2	121.0	123.0	119.0	126.0	122.0	118.0	114.0	109.0
H1228 L70	127.9	117.0	119.0	116.0	124.0	120.0	118.0	113.0	110.0
H1228 L80	123.1	113.0	113.0	111.0	119.0	116.0	113.0	110.0	105.0
H1229 L40	135.4	130.0	131.0	124.0	128.0	123.0	119.0	114.0	113.0
H1229 L50	136.0	129.0	130.0	125.0	131.0	125.0	122.0	117.0	117.0
H1229 L60	132.1	123.0	124.0	121.0	128.0	124.0	120.0	116.0	112.0
H1229 L70	129.8	119.0	120.0	118.0	126.0	122.0	120.0	116.0	113.0
H1229 L80	125.6	115.0	115.0	114.0	121.0	119.0	116.0	113.0	108.0

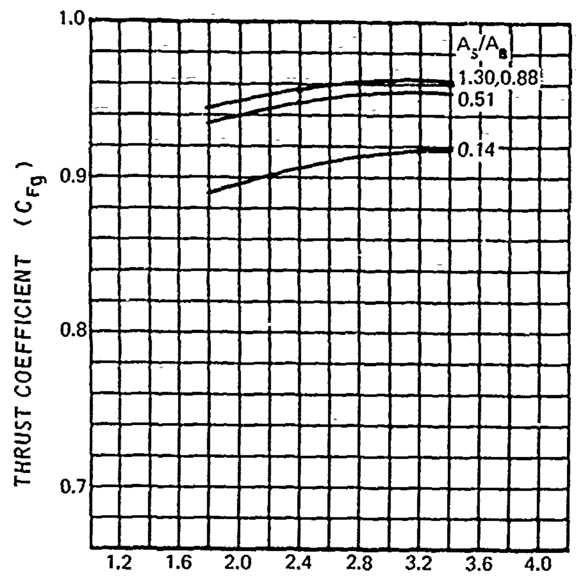
NOTE: DATA INCLUDES GROUND REFLECTION INTERFERENCE

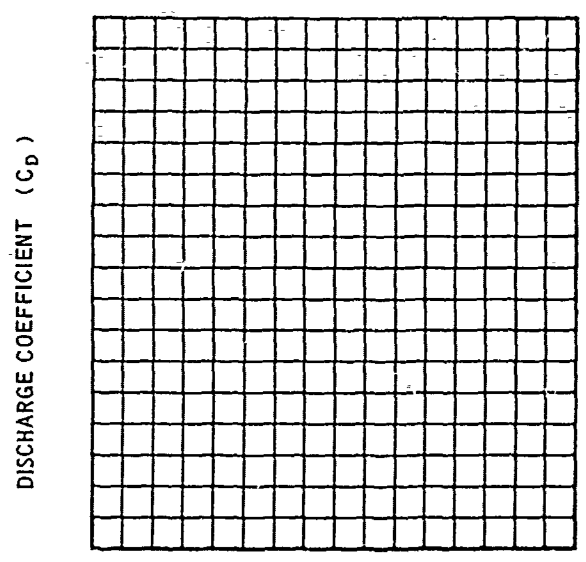
HM-AP-39

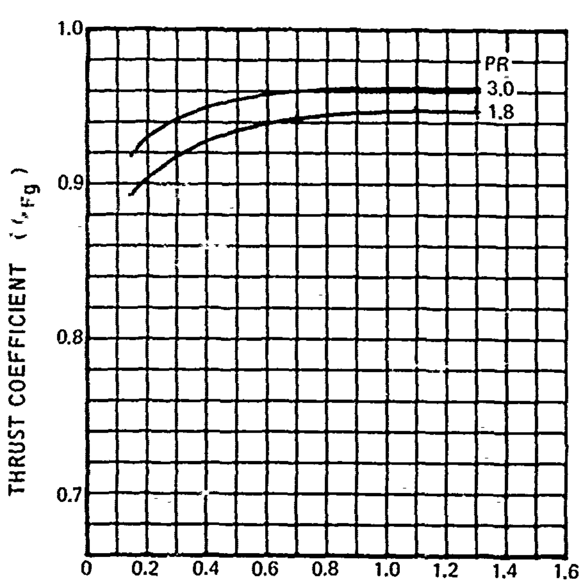


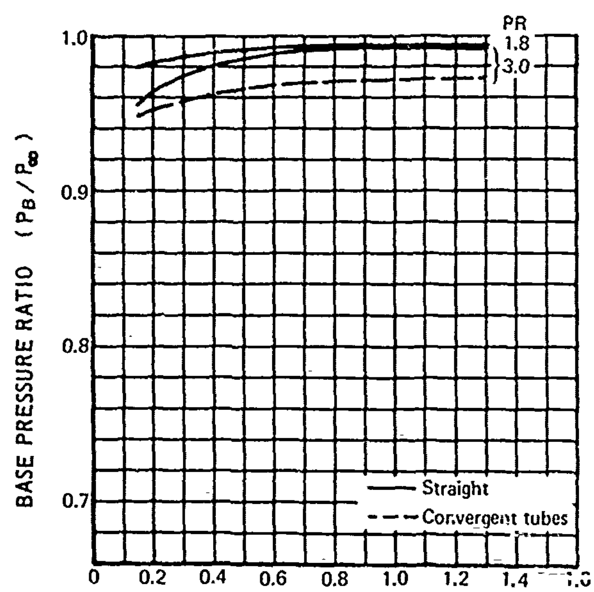
$$C_{Fg} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



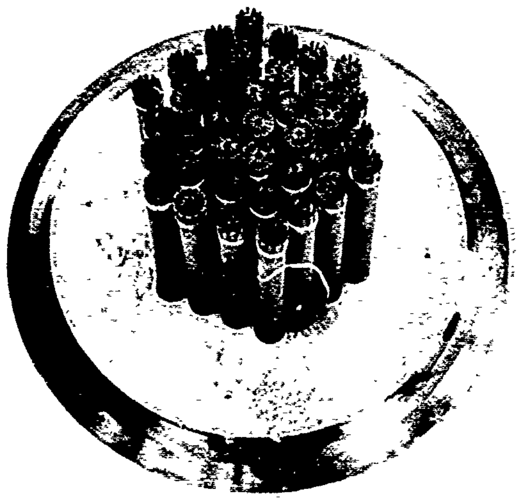






HM-AP-40 NOZZLE

37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY, AR3.33



Description:

The HM-AP-40 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have 12 spoke nozzle terminations. The tubes are inserted into a 17-inch diameter baseplate and are removeable.

Number of Elements: 37 tubes with 12 spoke ends

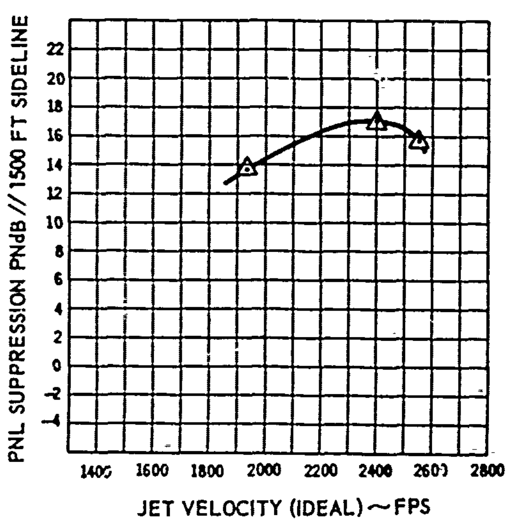
Area Ratio: 3.33

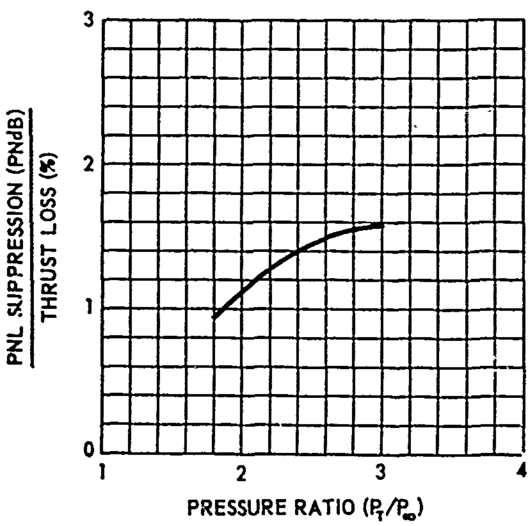
Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees

Length of Tubes:
- 7 inches
- 12 spoke terminations, AR = 1.86
- Flow area = 0.357 square inches
- Exit cant angle = 0 degrees
- Ventilation gutter angle = 77 degrees
- Spoke penetration = 75%

Material: 321 CRES

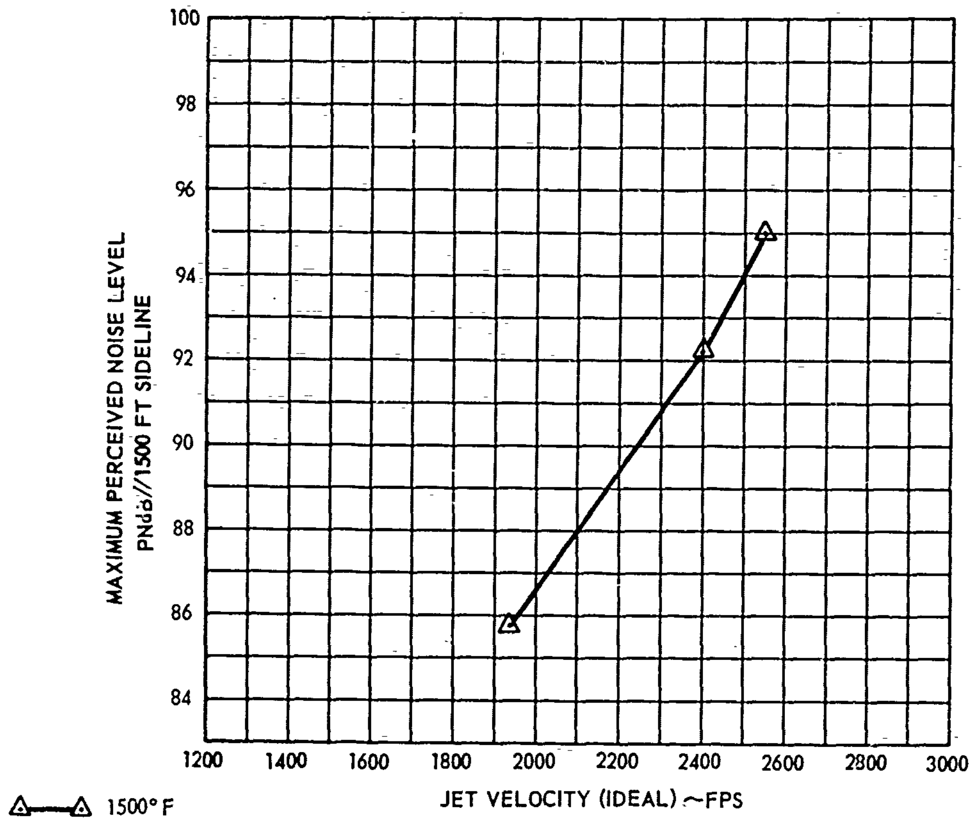




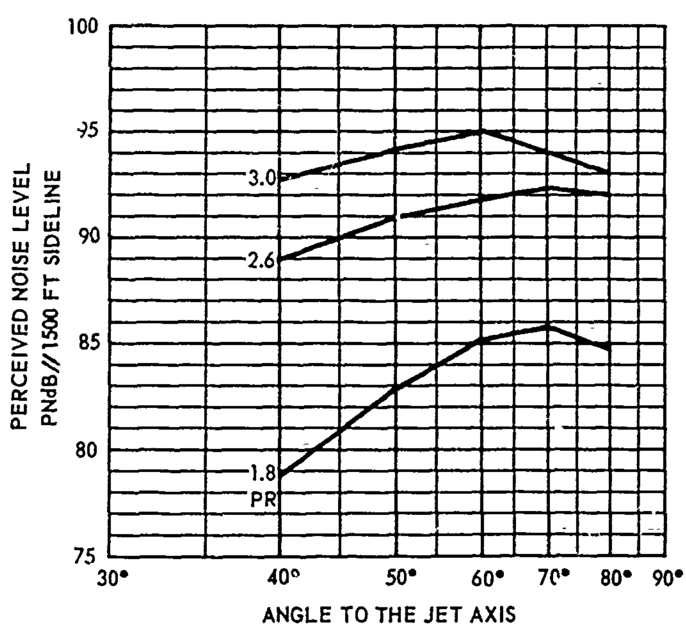
NOZZLE EXIT AREA (A_e): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-40 NOZZLE
(37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY)
AR 3.33
SCALE FACTOR: 8:1

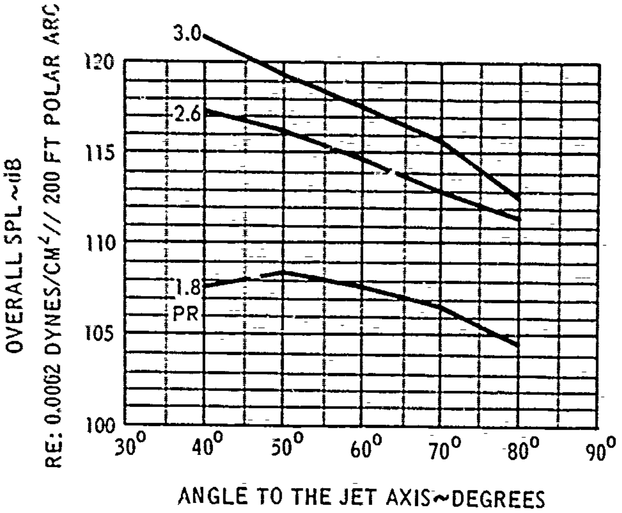


NOZZLE EXIT AREA (A_8): 5.9 FT²

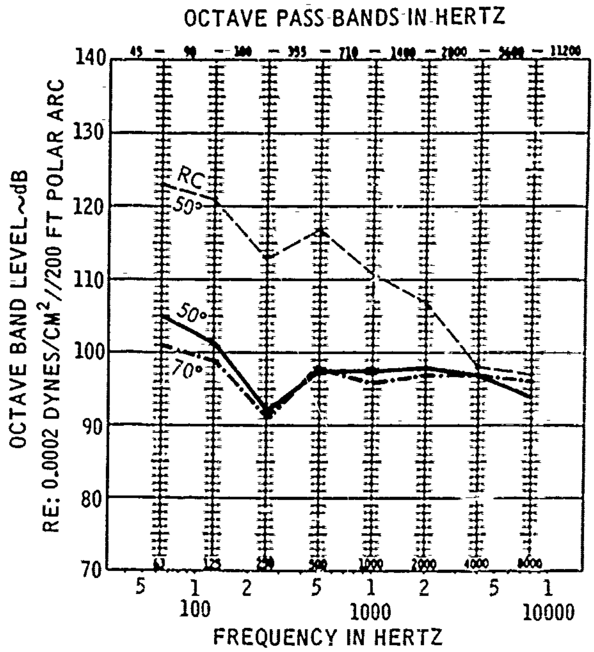


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

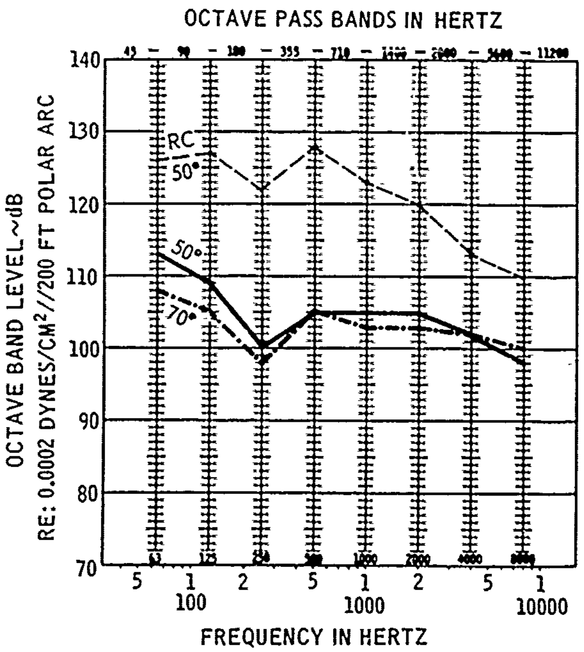


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

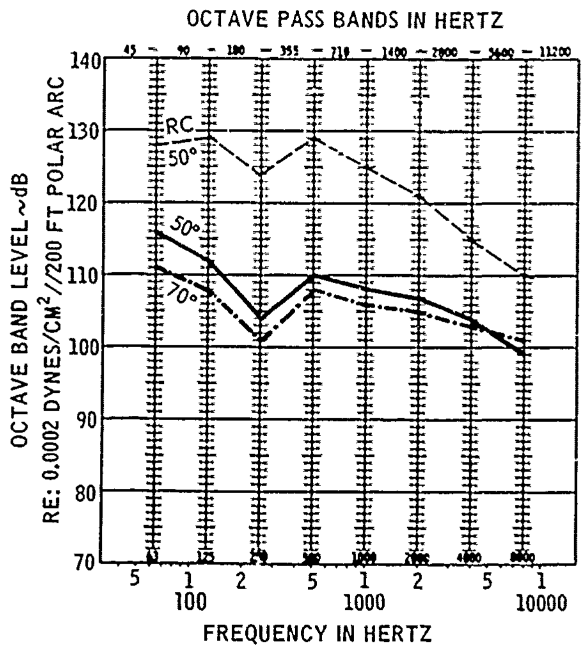


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1930 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

HM-AP-40 NOZZLE
(37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY)
AR 3.33
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2400 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2550 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-40

(37 Tube, 12 Spoke Ends, Hexagonal Array, AR 3.33)

Remarks

The HM-AP-40 nozzle was one of a series of 37 tube nozzles that were tested to determine the effect of area ratio on jet noise characteristics. The HM-AP-40 nozzle had the smallest area ratio and attained the best suppression values of the series when PR $\leq$ 2.6. At higher pressure ratios the low frequency portion of the spectrum becomes dominant due to jet coalescing noise and suppression values diminish. Tube length was varied from 1 inch to 7 inches with no effect on noise characteristics, see Reference D8.

Other 37 tube nozzles with 12 spoke terminations on each tube that were tested in this series ar'

HM-AP-18	AR 4.65
HM-AP-18a	AR 8.0
HM-AP-40	AR 3.33
HM-AP-41	AR 4.0
HM-AP-42	AR 5.2

See Reference D9.

HM-AP-40

Test Facility: Annex D (Cell #1)
Nozzle and Microphone Heights are 20 Inches

Date: November 20, 1967

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H 1137	1.8	1500°F	1930 fps	HM-AP-40
H 1138	2.6	"	2400	"
H 1139	3.0	"	2550	"
H 1144	1.8	1500°F	1930 fps	4.1-Inch Round Convergent Nozzle
H 1145	2.6	"	2400	"
H 1146	3.0	"	2550	"

Measured acoustic data is recorded in Reference D2.

NOZZLE TEST DATA

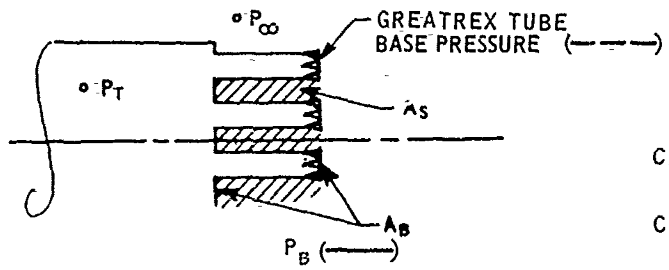
OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-40

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H1137L40	107.7	105.0	101.0	91.0	95.0	94.0	95.0	95.0	93.0
H1137L50	108.5	105.0	101.0	92.0	97.5	97.5	98.0	97.0	94.0
H1137L60	107.7	103.0	100.0	93.0	98.0	97.0	98.0	98.0	94.0
H1137L70	106.6	101.0	99.0	91.0	98.0	96.0	97.0	97.0	96.0
H1137L80	104.5	99.0	96.0	90.0	95.0	95.0	95.0	96.0	93.0
H1137L40	117.2	115.0	111.0	100.0	105.0	102.0	102.0	100.0	97.0
H1137L50	116.1	113.0	109.0	100.0	105.0	105.0	105.0	102.0	98.0
H1137L60	114.7	111.0	107.0	101.0	106.0	104.0	104.0	101.0	98.0
H1138L70	113.0	108.0	105.0	98.0	105.0	103.0	103.0	102.0	100.0
H1138L80	111.5	106.0	103.0	97.0	103.0	103.0	102.0	102.0	98.0
H1139L40	121.3	119.5	115.0	103.0	108.0	105.0	104.0	101.0	0.0
H1139L50	119.2	116.0	112.0	104.0	110.0	108.0	107.0	104.0	99.0
H1139L60	117.6	114.0	109.0	104.0	110.0	107.0	106.0	103.0	99.0
H1139L70	115.7	111.0	108.0	101.0	108.0	106.0	105.0	103.0	101.0
H1139L80	112.6	108.0	104.0	99.0	104.0	104.0	103.0	101.0	97.0
H1144L40	127.0	122.0	123.0	116.0	119.0	112.0	107.0	99.0	100.0
H1144L50	125.7	122.0	121.0	113.0	117.0	111.0	107.0	98.0	97.0
H1144L60	121.2	117.0	116.0	111.0	111.5	110.0	105.0	98.0	0.0
H1144L70	118.1	112.0	111.0	106.0	113.0	109.0	105.0	99.0	94.0
H1144L80	113.8	108.0	106.0	103.0	108.0	105.0	102.0	96.0	91.0
H1145L40	132.3	127.0	128.0	121.0	125.0	119.0	115.0	108.0	109.0
H1145L50	133.0	126.0	127.0	122.0	128.0	123.0	120.0	113.0	109.8
H1145L60	128.3	121.0	122.0	118.0	123.0	119.0	115.0	109.0	104.0
H1145L70	125.2	117.0	116.0	113.0	121.0	117.0	115.0	109.0	104.0
H1145L80	120.4	112.0	111.0	109.0	115.0	114.0	111.0	105.0	99.0
H1146L40	133.6	128.0	130.0	123.0	125.0	120.0	116.0	110.0	109.0
H1146L50	134.7	128.0	129.0	124.0	129.0	125.0	121.0	115.0	110.0
H1146L60	130.0	123.0	125.0	120.0	125.0	121.0	117.0	111.0	107.0
H1146L70	126.9	118.0	112.0	115.0	122.0	120.0	118.0	112.0	108.0
H1146L80	122.7	113.0	110.0	112.0	117.0	117.0	114.0	109.0	103.0

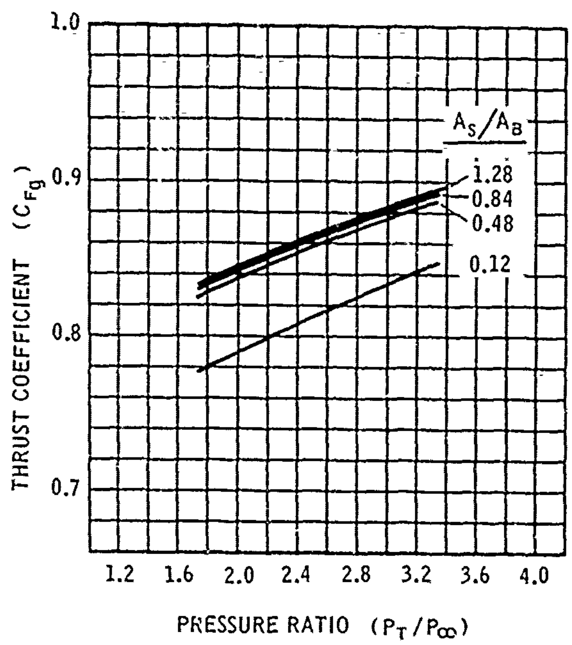
NOTE: DATA INCLUDES GROUND REFLECTION INTERFERENCE

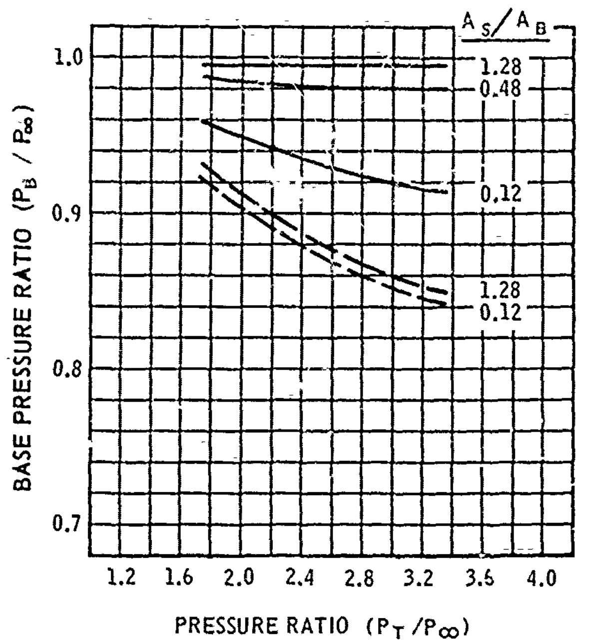
HM-AP-40

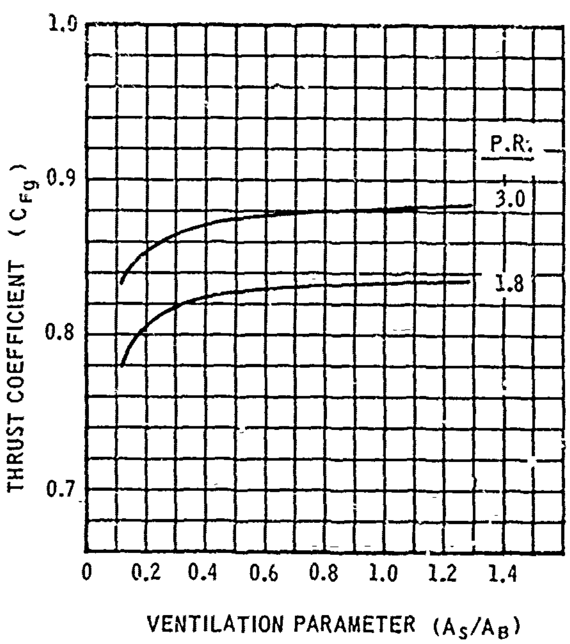


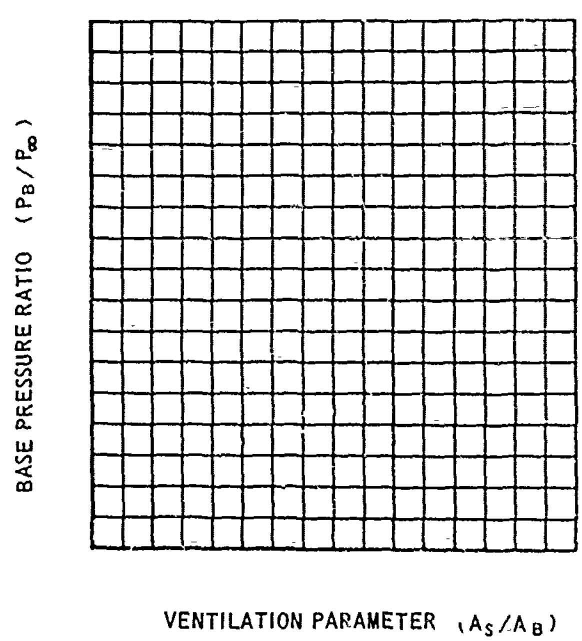
$$C_{F_g} = \frac{\text{(THRUST–DRAG) MEASURED}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{\text{(MASS FLOW) MEASURED}}{\text{IDEAL PRIMARY MASS FLOW}}$$

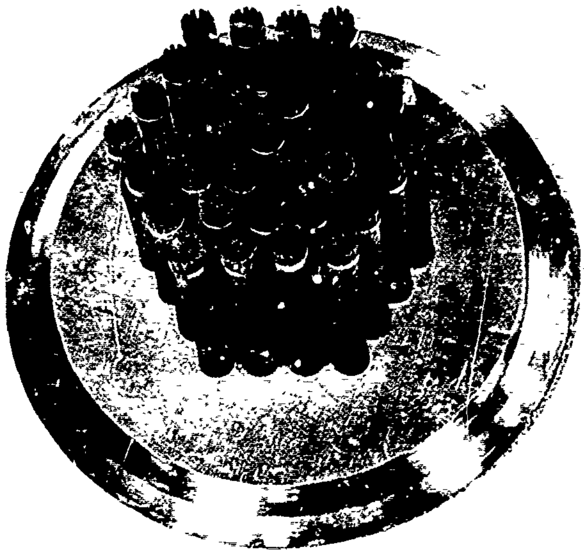








HM-AP-41 NOZZLE
(37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY, AR4.0)



Description:

The HM-AP-41 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have 12 spoke nozzle terminations. The tubes were inserted into a 17-inch diameter baseplate and were removeable.

Number of Elements: 37 tubes with 12 spoke ends

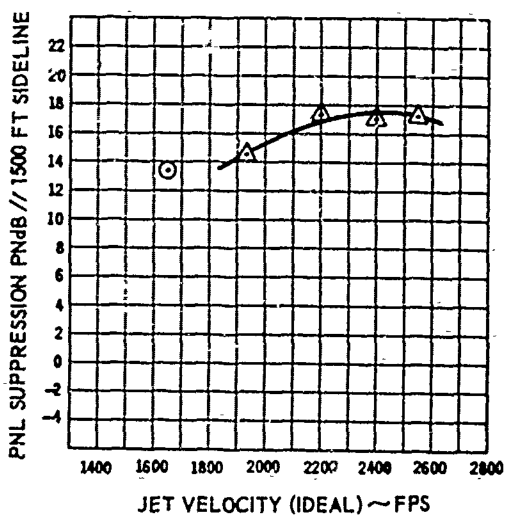
Area Ratio: 4.0

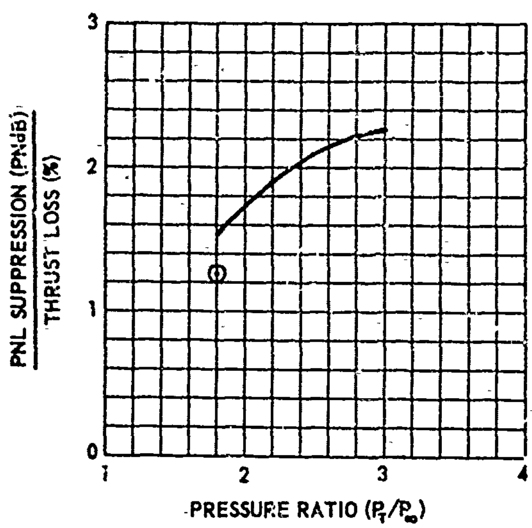
Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees

Length of Tubes:
- 7 inches
- 12 spoke terminations, AR = 1.86
- Flow area = 0.357 square inches
- Exit cant angle = 0 degrees
- Ventilation gutter angle = 77 degrees
- Spoke penetration = 75%

Material: 321 CRES



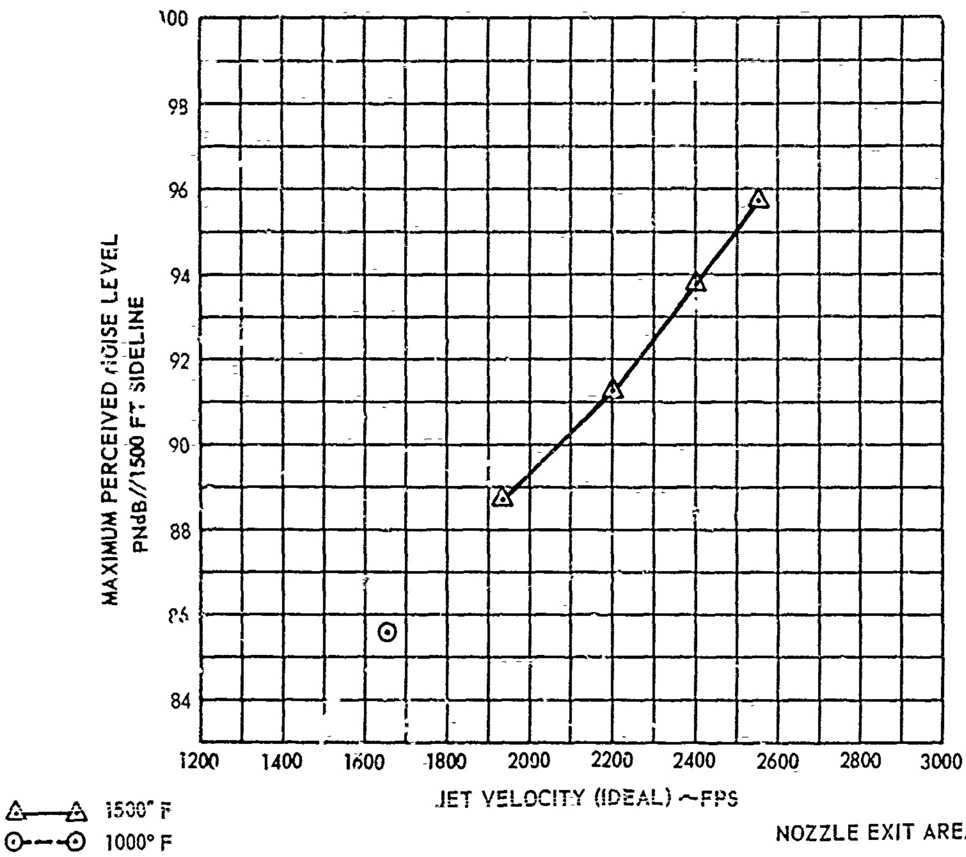


1500° F
1000° F

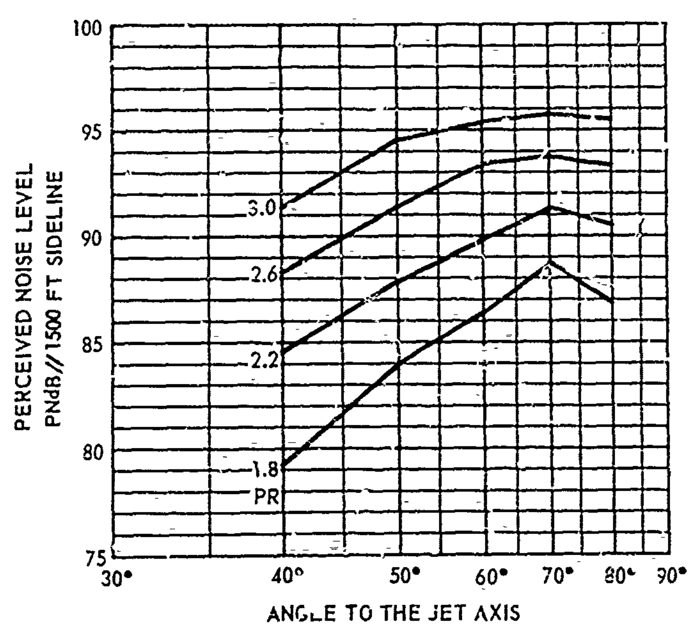
NOZZLE EXIT AREA (A_e): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-41 NOZZLE
(37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY)
AR 4.0
SCALE FACTOR: 8:1

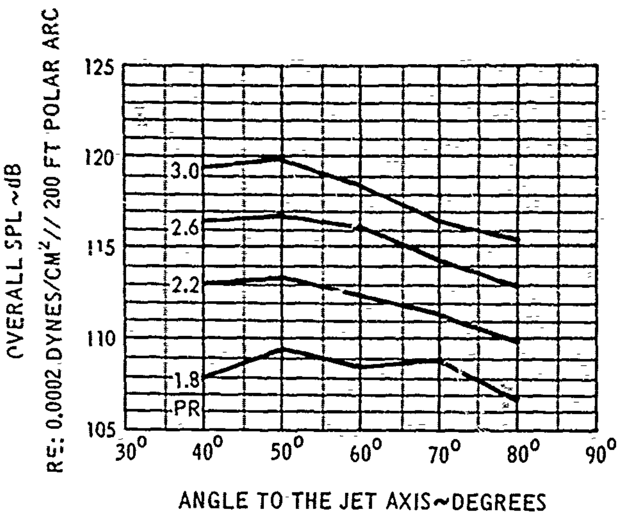


NOZZLE EXIT AREA (A_8): 5.9 FT²

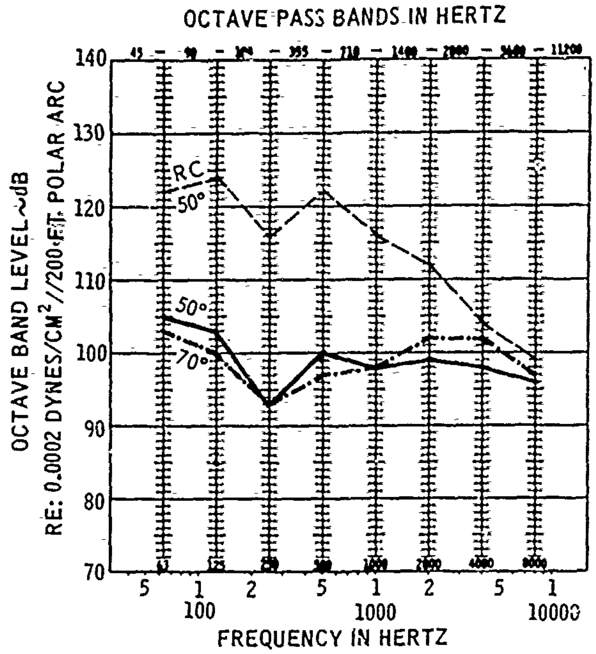


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

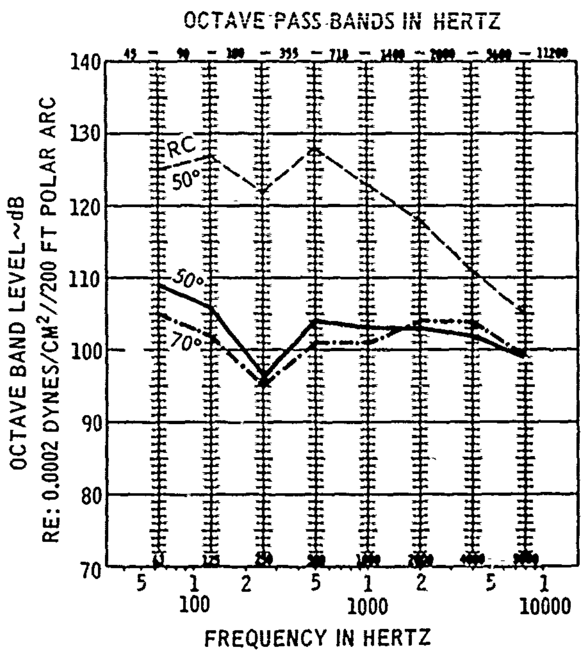


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

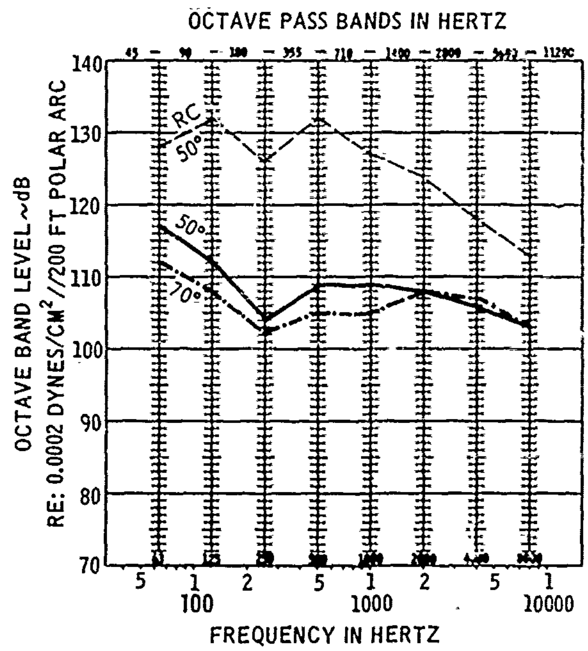


HM-AP-41 NOZZLE
(37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY)
AR 4.0
SCALE FACTOR: 8:1

PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-41 NOZZLE

(37 Tube, 12 Spoke Ends, Hexagonal Array, AR 4.0)

Remarks

The HM-AP-41 nozzle was one of a series of 37 tube hexagonal arrays tested where area ratio was a variable. This nozzle with an area ratio of 4.0 attained the best suppression value of 17.2 at PR = 3.0 and T_T = 1500°F. When effective tube length was varied from 7 inches to 1 inch, there was substantially no affect on the acoustic noise characteristics (Reference D8).

Several lined and unlined ejectors were tested with the HM-AP-41 nozzle (Reference D2). The unlined ejectors did not affect PNL suppression values significantly. One unlined ejector that was about 4 nozzle diameters (33.33 inches) in length did improve suppression by 0.7 PNdB. The lined ejectors demonstrated the potential of additional suppression of jet noise quite adequately. A one-inch thick TWF fiberglass blanket held in place by 0.035 inch stainless steel, 40% open mesh, was used for an acoustic absorbent liner. Additional suppression up to 7 PNdB was attained with a lined ejector. The lined ejector was most effective at low primary gas pressure ratios, e.g. PR = 1.8. At higher pressure ratios more low frequency noise is generated in the region of jet coalescence downstream of the exit plane and attenuation by the ejector diminishes. A peak suppression value of 22.8 PNdB was attained with the HM-AP-41 nozzle with lined ejector at PR = 2.2 and T_T = 1500°F . See Reference D9.

HM-AP-41

Test Facility: Annex D (Cell #1)
Nozzle and Microphone Heights are 20 Inches

Date:

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
3309	1.8	1000°F	1659 fps	HM-AP-41
3310	1.8	1500°F	1923	"
3311	2.2	"	2202	"
3312	2.6	"	2402	"
3313	3.0	"	2555	"
3304	1.8	1000°F	1659 fps	4.1-Inch Round Convergent Nozzle
3305	1.8	1500°F	1923	"
3306	2.2	"	2202	"
3307	2.6	"	2402	"
3308	3.0	"	2555	"

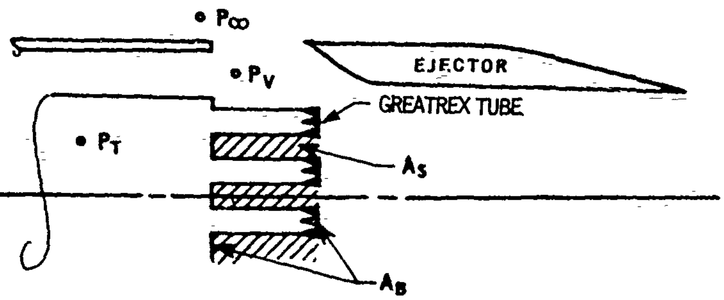
HM-AP-41 NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES / CM²// 25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
3304AL40	126.2	121.0	123.0	113.0	117.0	111.0	107.0	101.0	93.0
3304AL50	124.2	119.0	120.0	112.0	117.0	111.0	107.0	98.0	94.0
3304AL60	120.5	115.0	114.0	108.0	115.0	111.0	105.0	98.0	91.0
3304AL70	116.2	110.0	109.0	105.0	111.0	105.0	105.0	99.0	92.0
3304AL80	115.0	108.0	108.0	104.0	110.0	106.0	103.0	98.0	92.0
3305AL40	129.5	124.0	125.0	117.0	123.0	116.0	113.0	107.0	101.0
3305AL50	128.2	122.0	124.0	116.0	122.0	116.0	112.0	104.0	99.0
3305AL60	124.4	118.0	119.0	113.0	119.0	113.0	110.0	103.0	96.0
3305AL70	119.6	113.0	113.0	108.0	114.0	110.0	109.0	104.0	96.0
3305AL80	118.6	111.0	111.0	107.0	114.0	110.0	107.0	101.0	96.0
3306AL40	132.7	126.0	128.0	121.0	127.0	121.0	118.0	113.0	107.0
3306AL50	132.8	125.0	127.0	122.0	128.0	123.0	118.0	111.0	105.0
3306AL60	128.6	120.0	123.0	117.0	124.0	119.0	115.0	109.0	103.0
3306AL70	123.9	116.0	116.0	113.0	119.0	115.0	114.0	109.0	102.0
3306AL80	121.6	113.0	113.0	111.0	117.0	114.0	111.0	106.0	101.0
3307AL40	135.0	129.0	131.0	123.0	128.0	122.0	119.0	115.0	109.0
3307AL50	135.1	127.0	130.0	124.0	130.0	124.0	122.0	115.0	111.0
3307AL60	131.6	123.0	126.0	120.0	127.0	122.0	118.0	112.0	107.0
3307AL70	126.5	118.0	119.0	115.0	122.0	117.0	116.0	112.0	106.0
3307AL80	124.9	115.0	116.0	113.0	121.0	117.0	115.0	110.0	105.0
3308AL40	135.7	130.0	131.0	125.0	129.0	123.0	120.0	116.0	110.0
3308AL50	137.0	128.0	132.0	126.0	132.0	127.0	124.0	118.0	113.0
3308AL60	133.9	124.0	127.0	123.0	130.0	125.0	121.0	116.0	110.0
3308AL70	128.5	119.0	120.0	117.0	124.0	120.0	119.0	116.0	109.0
3308AL80	127.5	116.0	117.0	116.0	123.0	120.0	120.0	114.0	109.0
3309AL40	106.3	103.0	100.0	87.0	95.0	93.0	94.0	95.0	92.0
3309AL50	108.1	104.0	102.0	91.0	98.0	96.0	97.0	96.0	94.0
3309AL60	107.4	103.0	100.0	90.0	97.0	97.0	98.0	97.0	94.0
3309AL70	106.7	102.0	99.0	90.0	94.0	94.0	98.0	99.0	95.0
3309AL80	104.1	99.0	97.0	87.0	92.0	93.0	95.0	95.0	94.0
3310AL40	108.0	104.0	102.0	90.0	97.0	96.0	97.0	97.0	94.0
3310AL50	109.5	105.0	103.0	93.0	100.0	98.0	99.0	98.0	96.0
3310AL60	108.7	103.0	102.0	93.0	99.0	99.0	100.0	98.0	96.0
3310AL70	109.0	103.0	100.0	93.0	97.0	98.0	102.0	102.0	97.0
3310AL80	106.9	101.0	98.0	90.0	96.0	97.0	98.0	99.0	98.0
3311AL40	113.0	109.0	105.0	95.0	104.0	102.0	103.0	102.0	99.0
3311AL50	113.3	109.0	106.0	96.0	104.0	103.0	103.0	102.0	99.0
3311AL60	112.4	107.0	106.0	96.0	104.0	102.0	103.0	101.0	99.0
3311AL70	111.3	105.0	102.0	95.0	101.0	101.0	104.0	104.0	99.0
3311AL80	109.9	103.0	101.0	93.0	100.0	101.0	102.0	102.0	100.0
3312AL40	116.3	112.0	109.0	100.0	107.0	106.0	106.0	105.0	101.0
3312AL50	116.8	113.0	110.0	100.0	107.0	106.0	106.0	104.0	101.0
3312AL60	116.2	112.0	109.0	100.0	107.0	106.0	106.0	104.0	102.0
3312AL70	114.3	109.0	106.0	99.0	103.0	104.0	106.0	106.0	102.0
3312AL80	113.0	107.0	105.0	97.0	102.0	103.0	104.0	105.0	103.0
3313AL40	119.4	116.0	112.0	103.0	109.0	109.0	108.0	107.0	102.0
3313AL50	119.9	117.0	112.0	104.0	109.0	109.0	108.0	106.0	103.0
3313AL60	118.5	115.0	111.0	103.0	109.0	108.0	107.0	105.0	102.0
3313AL70	116.4	112.0	108.0	102.0	105.0	105.0	108.0	107.0	103.0
3313AL80	115.3	110.0	107.0	100.0	105.0	106.0	106.0	106.0	104.0

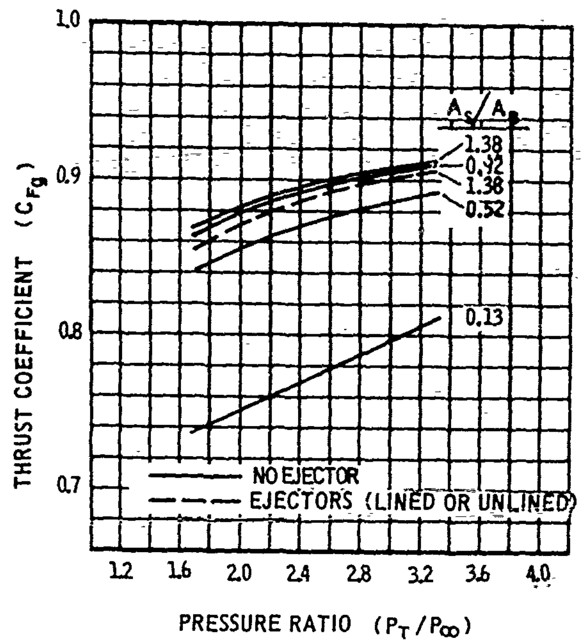
DATA INCLUDES GROUND REFLECTION INTERFERENCE

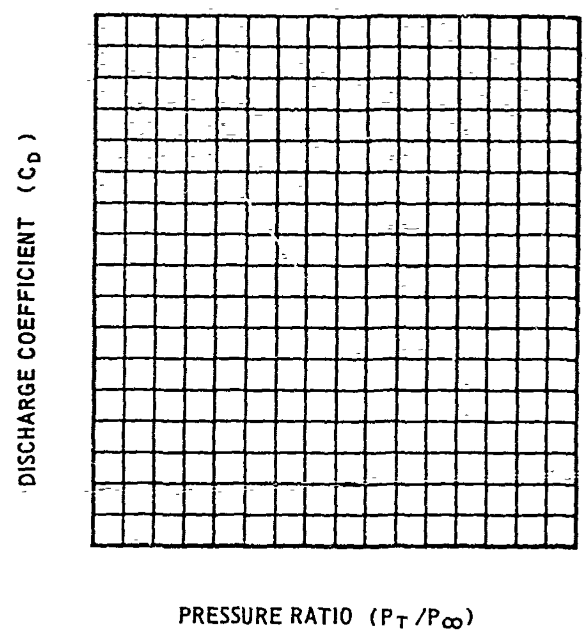
HM-AP-41

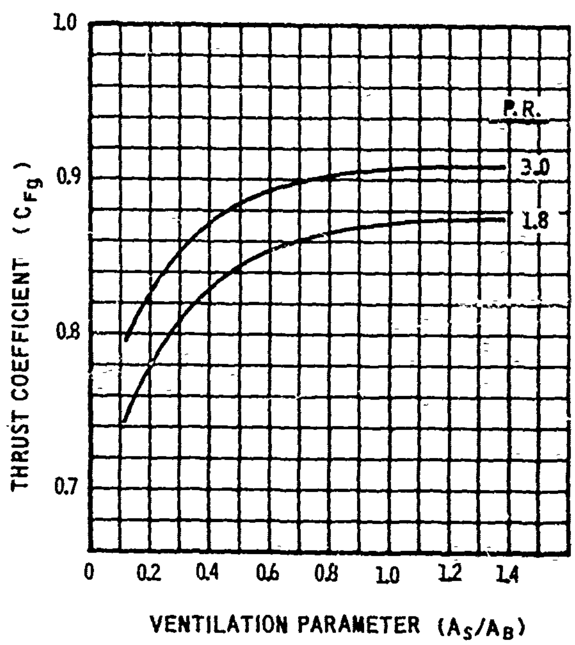


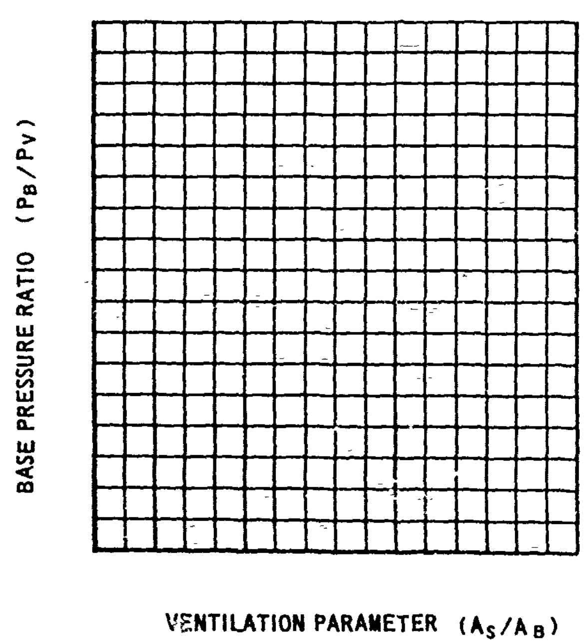
$$C_{F_g} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



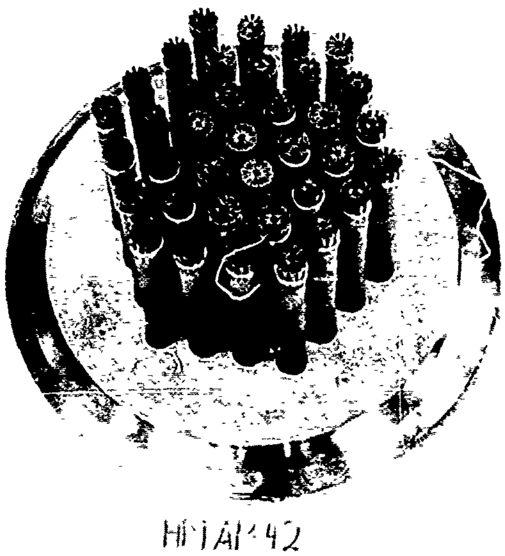






HM-AP-42 NOZZLE

(37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY, AR 5.2)



Description:

The HM-AP-42 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have 12 spoke nozzle terminations. The tubes were inserted into a 17-inch diameter baseplate and were removeable.

Number of Elements: 37 tubes with 12 spoke ends

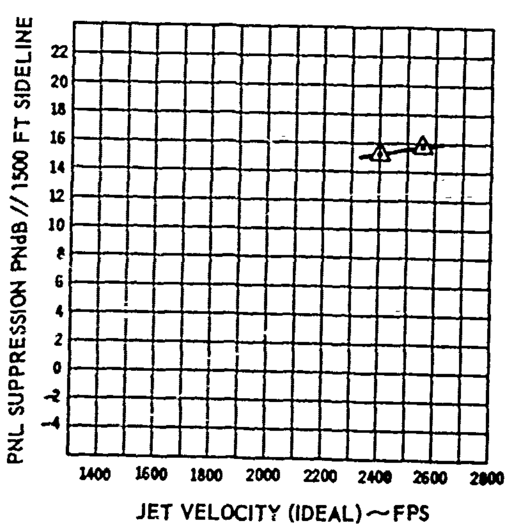
Area Ratio: 5.2

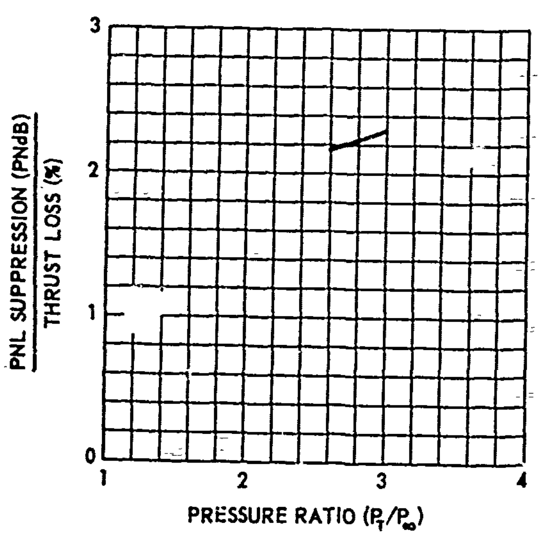
Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees

Length of Tubes:
- 7 inches
- 12 spoke terminaiions, AR = 1.86
- Flow area = 0.357 square inches
- Exit cant angle = 0 degrees
- Ventilation gutter angle = 77 degrees
- Spoke penetration = 75%

Material: 321 CRES



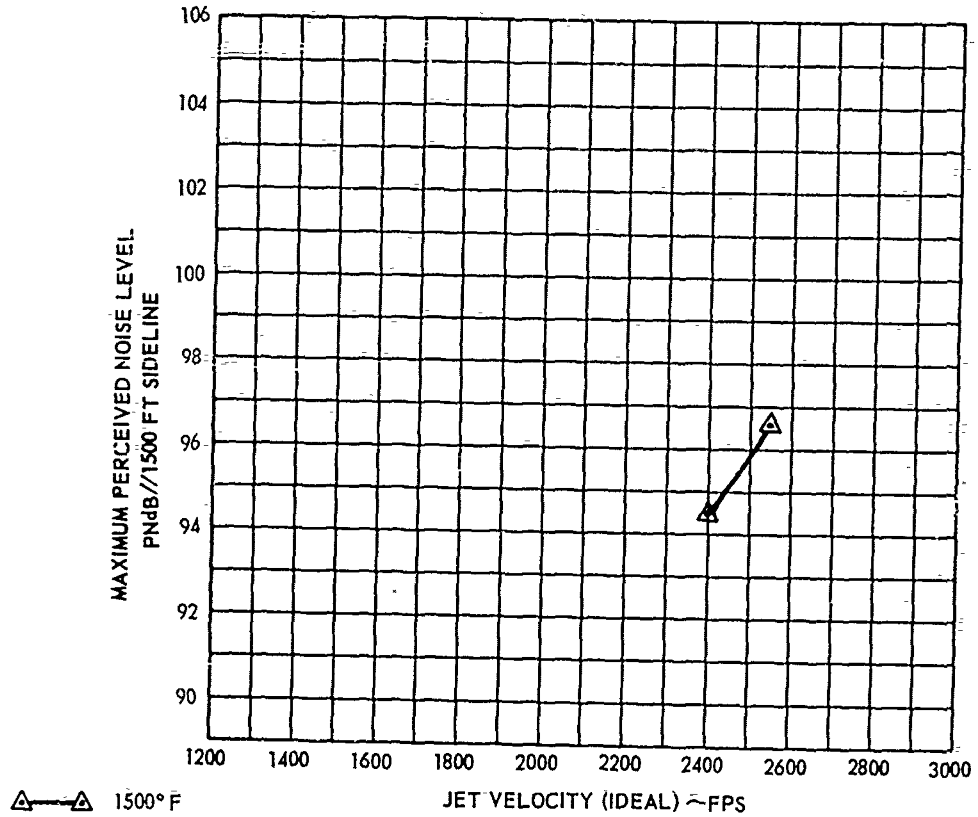


△—△ 1500° F

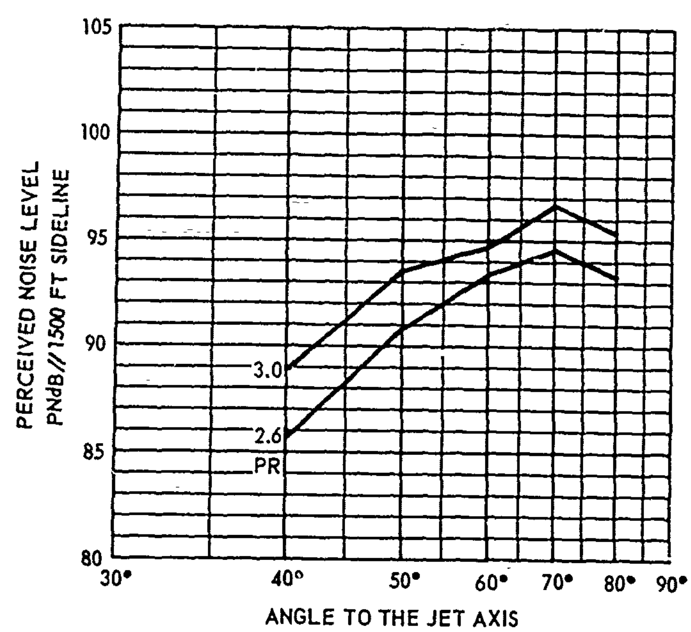
NOZZLE EXIT AREA (A_e): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-42 NOZZLE
(37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY)
AR 5.2
SCALE FACTOR: 8:1

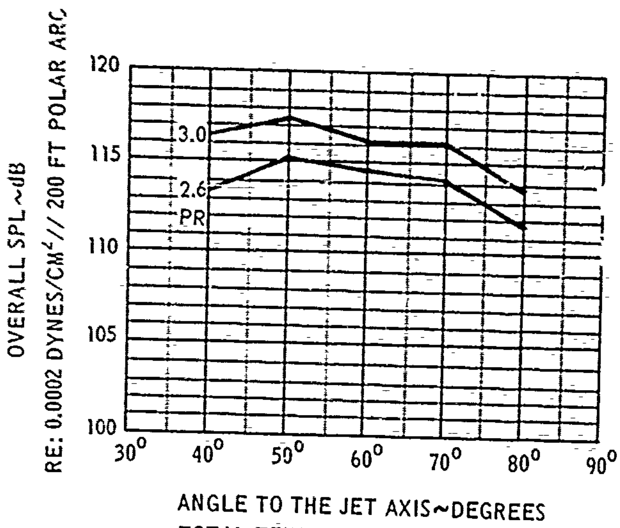


NOZZLE EXIT AREA (A_8): 5.9 FT²

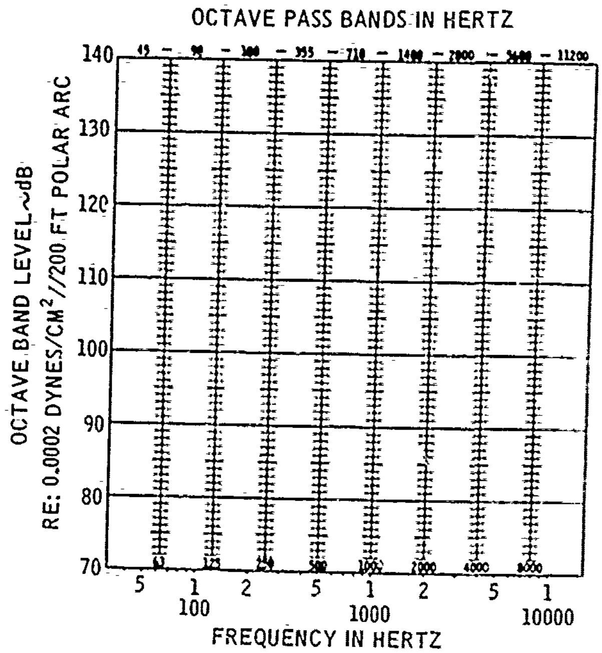


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

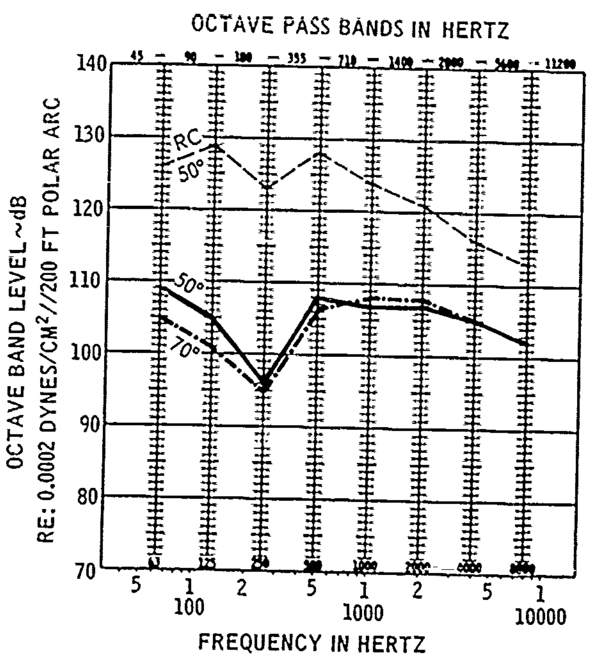


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

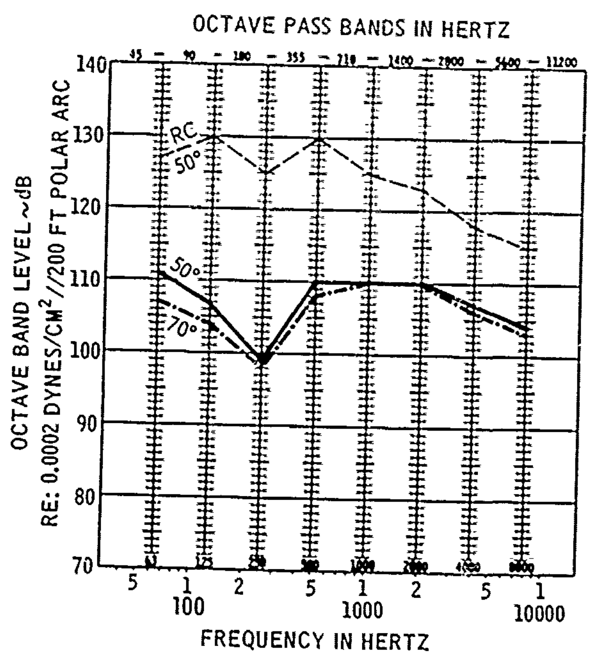


PRESSURE RATIO:
TOTAL TEMPERATURE:
JET VELOCITY (IDEAL):
NOZZLE EXIT AREA (A_8):

HM-AP-42 NOZZLE
(37 TUBE, 12 SPOKE ENDS, HEXAGONAL ARRAY)
AR 5.2
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2400 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2550 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-42

(37 Tube, 12 Spoke Ends, Hexagonal Array, AR 5.2)

Remarks:

The HM-AP-42 nozzle was one of a series of 37 tube nozzles that were tested to determine the effect of area ratio on jet noise characteristics. Tube length was varied from 1 inch to 7 inches with no significant differences noted in jet noise characteristics, see Reference D8. Other 37 tube nozzles with 12 spoke terminations on each tube that was tested in this series are:

HM-AP-18	AR 4.65
HM-AP-18a	AR 8.0
HM-AP-40	AR 3.33
HM-AP-41	AR 4.0
HM-AP-42	AR 5.2

See Reference D9.

HM-AP-42

Test Facility: Annex D (Cell #1)
Nozzle and Microphone Heights are 20 Inches

Date:

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H 1158	2.6	1500°F	2400 fps	HM-AP-42
H 1159	3.0	"	2550	"
H 1126	2.6	1500°F	2400 fps	4.1-Inch Round Convergent Nozzle
H 1127	3.0	"	2550	"

Measured acoustic data is recorded in Reference D2.

NOZZLE TEST DATA

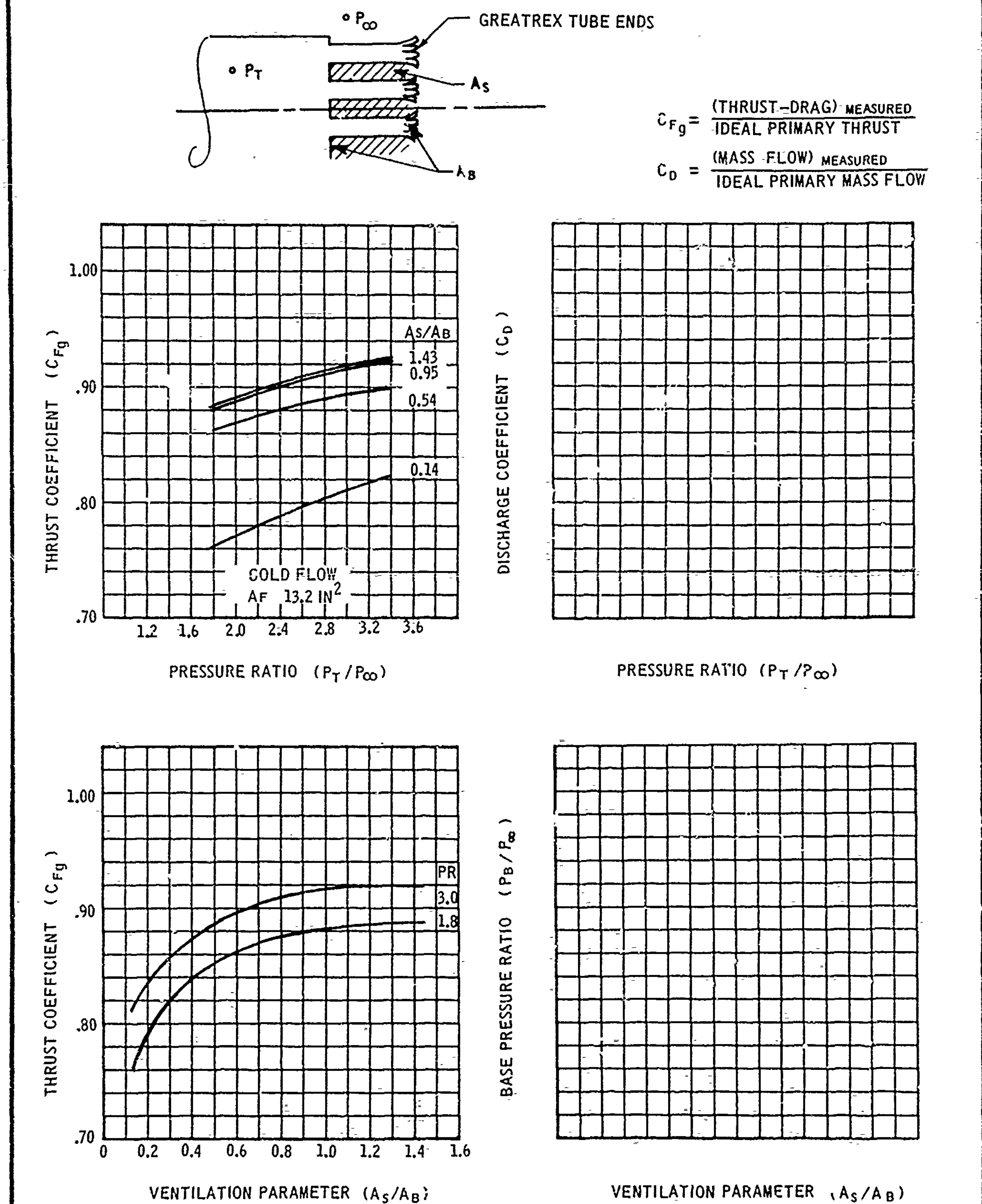
OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM²//25 FT

HM-AP-42

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H1158L40	113.3	108.0	103.0	96.0	105.0	106.0	105.0	102.0	99.0
H1158L50	115.1	109.0	105.0	96.0	108.0	107.0	107.0	105.0	102.0
H1158L60	114.6	107.0	103.0	97.0	107.0	108.0	108.0	104.0	100.0
H1158L70	114.2	105.0	101.0	95.0	106.0	108.0	108.0	105.0	102.0
H1158L80	111.8	102.0	99.0	94.0	100.0	106.0	106.0	104.0	100.0
H1159L40	116.4	111.0	106.0	99.0	108.0	110.0	108.0	104.0	101.0
H1159L50	117.5	111.0	107.0	99.0	110.0	110.0	110.0	107.0	104.0
H1159L60	116.1	109.0	105.0	99.0	109.0	109.0	109.0	106.0	101.0
H1159L70	116.1	107.0	104.0	98.0	108.0	110.0	110.0	106.0	103.0
H1159L80	113.8	105.0	102.0	97.0	100.0	108.0	108.0	106.0	101.0
H1126L40	133.6	127.0	130.0	123.0	126.0	121.0	117.0	111.0	111.0
H1126L50	133.9	126.0	129.0	123.0	128.0	124.0	121.0	116.0	113.0
H1126L60	129.1	122.0	123.0	119.0	123.0	120.0	118.0	112.0	106.0
H1126L70	125.5	117.0	117.0	113.0	120.0	119.0	116.0	111.0	106.0
H1126L80	121.4	113.0	112.0	110.0	116.0	115.0	112.0	107.0	100.0
H1127L40	135.3	129.0	132.0	124.0	127.0	122.0	118.0	112.0	112.0
H1127L50	135.4	127.0	130.0	125.0	130.0	125.0	123.0	118.0	115.0
H1127L60	130.7	123.0	124.0	121.0	125.0	122.0	119.0	114.0	109.0
H1127L70	127.9	119.0	118.0	116.0	122.0	122.0	119.0	114.0	109.0
H1127L80	123.6	114.0	113.0	112.0	118.0	118.0	115.0	110.0	0.0

THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-42

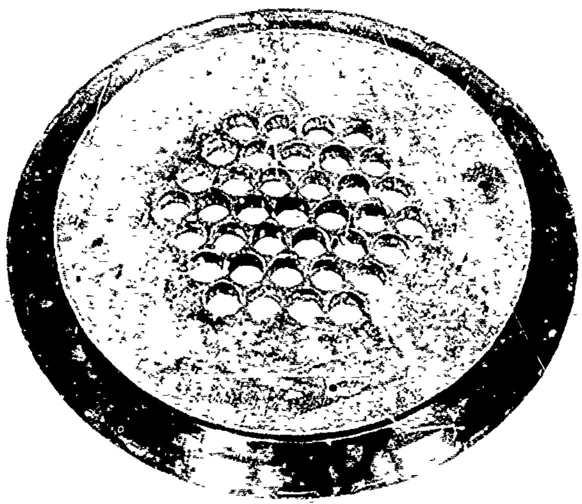


$$C_{F_g} = \frac{(\text{THRUST} - \text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$

HM-AP-43 NOZZLE

(37 TUBE HEXAGONAL ARRAY, AR3.33)



BASE PLATE WITH TUBES REMOVED

Description:

The HM-AP-43 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have round convergent terminations. The tubes were inserted into a 17-inch diameter base plate and were removeable.

Number of Elements: 37 tubes with round convergent ends

Area Ratio: 3.33

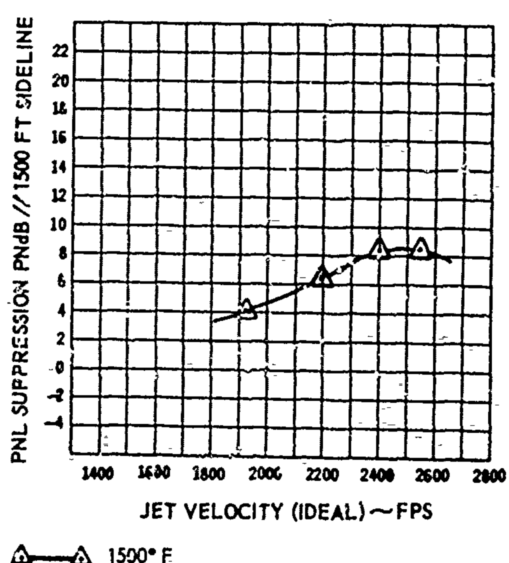
Flow Area: 13.2 square inches

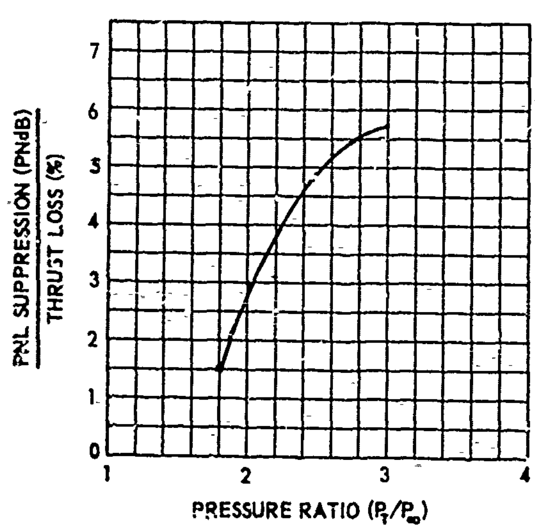
Exit Cant Angle: 0 degrees

Length of Tubes: 7 inches

Tube Exit Diameter: 0.674 inches

Material: 321 CRES

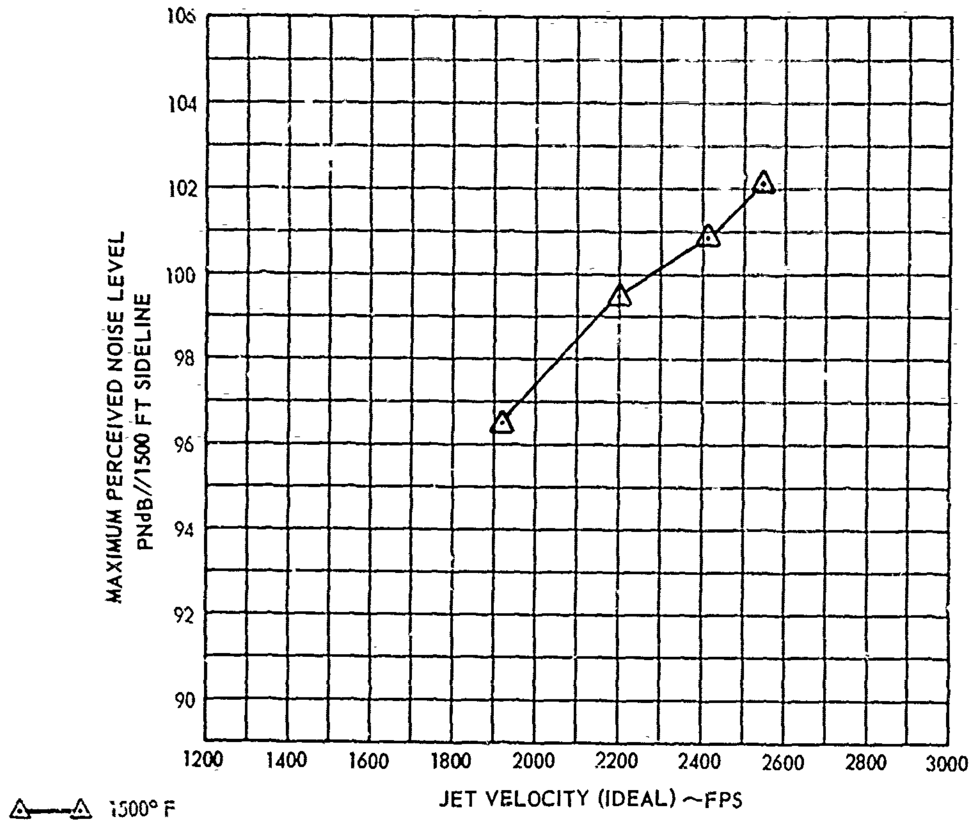




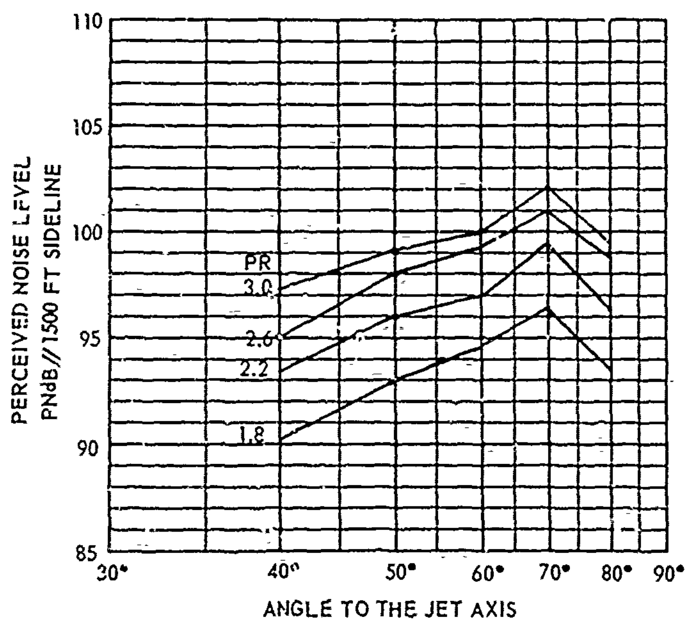
NOZZLE EXIT AREA (A_e): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-43 NOZZLE
(37 TUBE HEXAGONAL ARRAY)
AR 3.33
SCALE FACTOR: 8:1

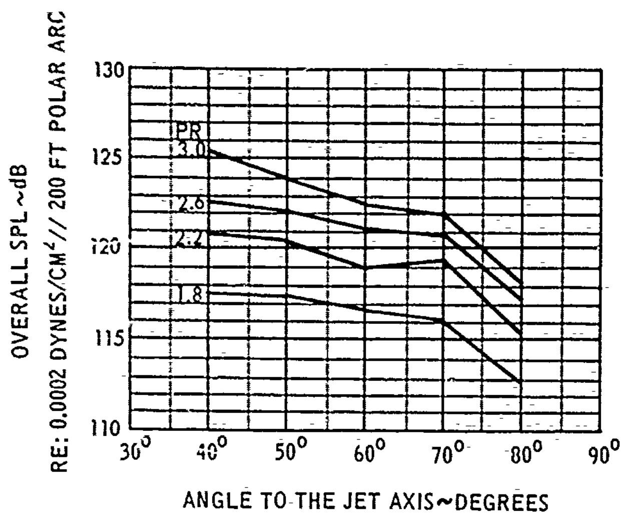


NOZZLE EXIT AREA (A_8): 5.9 FT²

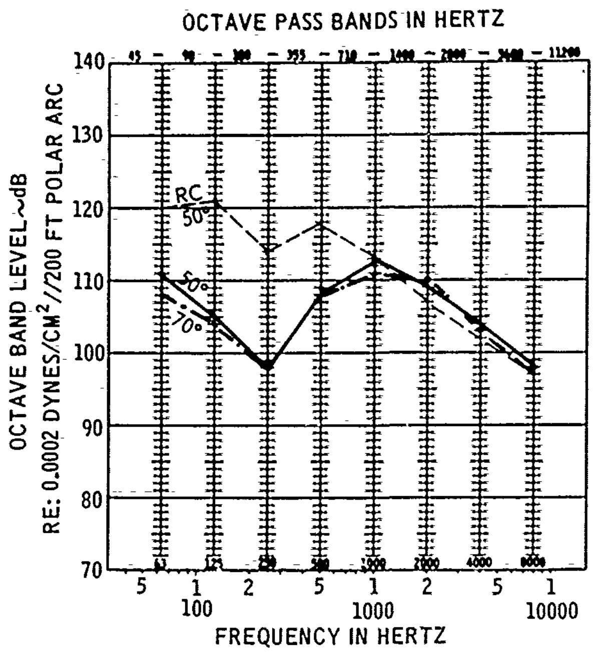


TOTAL TEMPERATURE (T_t): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

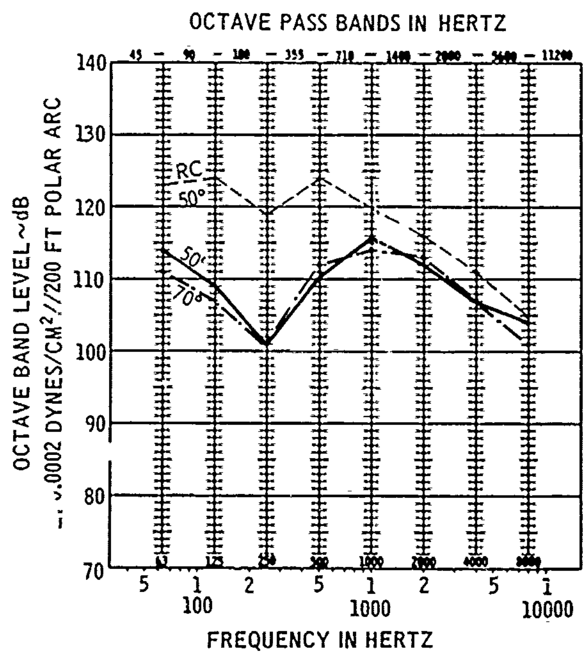


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

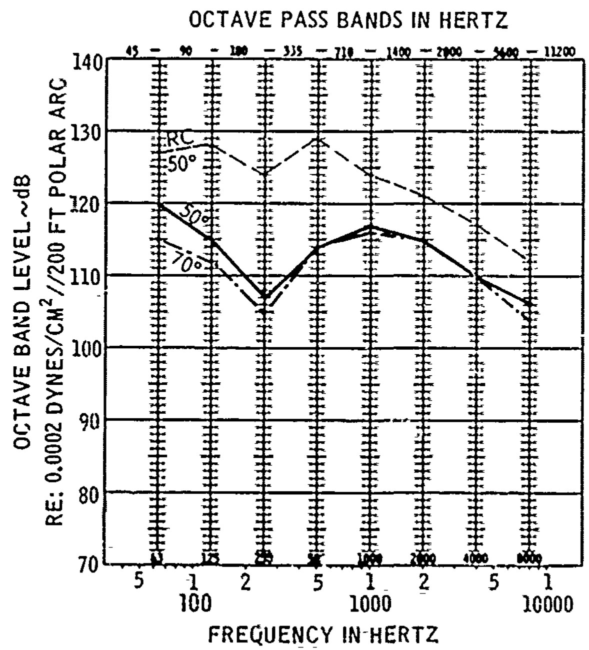


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

HM-AP-43 NOZZLE
(37 TUBE HEXAGONAL ARRAY)
AR 3.33
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-43

(37 Tube Hexagonal Array, AR = 3.33)

Remarks

The HM-AP-43 nozzle was tested with several different tube lengths, see Reference D19. Nozzle configurations with effective tube lengths of 7 inches, 5 inches, 3 inches or 1 inch showed essentially no differences in jet noise characteristics.

A close-fitting unlined hexagonal ejector was tested with the HM-AP-43 nozzle, Ref. D22. The length of the ejector was six inches. PNL suppression with the ejector installed improved by 1.5 to 2.5 PNdB. The ejector was most effective at the lower pressure ratios (PR < 3.0) affecting the high frequency portion of the spectrum.

HM-AP-43

Test Facility: Annex D
Nozzle and Microphone Heights are 20 Inches

Date: March 28, 1968

T_{amb}: not available

R.H.: not available

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
2867	1.8	540°F	1370 fps	HM-AP-43
2868	1.8	1000°F	1659	"
2869	1.8	1500°F	1923	"
2870	2.2	"	2202	"
2871	2.6	"	2402	"
2872	3.0	"	2555	"
2873	1.8	540°F	1370 fps	4.1-Inch Round Convergent Nozzle
2874	1.8	1000°F	1659	"
2875	1.8	1500°F	1923	"
2876	2.2	"	2202	"
2877	2.6	"	2402	"
2878	3.0	"	2555	"

NOZZLE TEST DATA

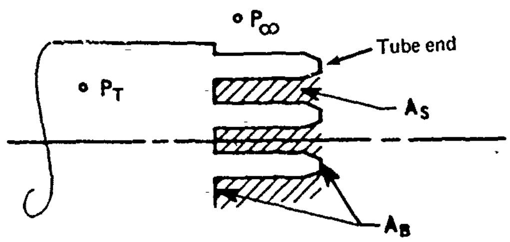
OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

HM-AP-43

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
2867 L40	112.4	108.0	100.0	93.0	104.0	107.0	102.0	97.0	93.0
2867 L50	111.8	108.0	101.0	94.0	104.0	105.0	100.0	95.0	93.0
2867 L60	111.3	107.0	101.0	94.0	104.0	104.0	101.0	98.0	93.0
2867 L70	109.9	104.0	98.0	92.0	101.0	104.0	103.0	97.0	93.0
2867 L80	107.1	101.0	95.0	90.0	100.0	101.0	99.0	95.0	88.0
2868 L40	116.1	113.0	108.0	93.0	104.0	109.0	105.0	99.0	94.0
2868 L50	117.4	114.0	111.0	97.0	106.0	109.0	106.0	100.0	96.0
2868 L60	117.4	114.0	111.0	99.0	108.0	107.0	105.0	101.0	95.0
2868 L70	115.3	111.0	108.0	97.0	105.0	107.0	107.0	101.0	96.0
2868 L80	112.4	109.0	104.0	93.0	102.0	104.0	102.0	98.0	94.0
2869 L40	117.7	110.0	104.0	97.0	108.0	114.0	110.0	105.0	99.0
2869 L50	117.3	111.0	105.0	98.0	108.0	113.0	109.0	104.0	98.0
2869 L60	116.7	111.0	106.0	98.0	109.0	111.0	108.0	103.0	97.0
2869 L70	116.1	108.0	104.0	98.0	108.0	111.0	110.0	103.0	97.0
2869 L80	112.8	105.0	100.0	94.0	105.0	108.0	105.0	102.0	96.0
2870 L40	120.8	114.0	108.0	100.0	110.0	116.0	114.0	108.0	108.0
2870 L50	120.3	114.0	109.0	101.0	110.0	116.0	112.0	107.0	104.0
2870 L60	119.0	113.0	109.0	102.0	111.0	113.0	111.0	106.0	100.0
2870 L70	119.3	111.0	107.0	101.0	112.0	114.0	113.0	107.0	101.0
2870 L80	115.2	106.0	103.0	97.0	108.0	110.0	108.0	105.0	98.0
2871 L40	122.8	118.0	113.0	102.0	113.0	117.0	114.0	109.0	106.0
2871 L50	122.2	117.0	112.0	104.0	112.0	116.0	115.0	109.0	105.0
2871 L60	121.2	115.0	112.0	104.0	113.0	115.0	113.0	109.0	104.0
2871 L70	120.8	112.0	109.0	103.0	113.0	116.0	114.0	108.0	103.0
2871 L80	117.3	109.0	106.0	99.0	110.0	111.0	111.0	107.0	100.0
2872 L40	125.2	121.0	117.0	105.0	115.0	118.0	116.0	110.0	107.0
2872 L50	124.1	120.0	115.0	107.0	114.0	117.0	115.0	110.0	106.0
2872 L60	122.5	117.0	114.0	106.0	114.0	116.0	113.0	110.0	104.0
2872 L70	122.0	115.0	112.0	105.0	114.0	116.0	115.0	110.0	104.0
2872 L80	118.2	111.0	108.0	102.0	110.0	112.0	111.0	108.0	100.0
2873 L40	119.0	116.0	114.0	104.0	109.0	105.0	99.0	91.0	93.0
2873 L50	116.4	113.0	110.0	104.0	109.0	105.0	92.0	92.0	92.0
2873 L60	113.9	109.0	107.0	101.0	108.0	104.0	100.0	94.0	91.0
2873 L70	112.5	107.0	104.0	100.0	107.0	104.0	101.0	93.0	90.0
2873 L80	109.5	103.0	101.0	97.0	105.0	101.0	97.0	92.0	86.0
2874 L40	125.5	122.0	121.0	111.0	116.0	111.0	104.0	96.0	101.0
2874 L50	124.2	121.0	119.0	110.0	115.0	110.0	104.0	96.0	100.0
2874 L60	120.3	116.0	115.0	106.0	113.0	109.0	105.0	98.0	94.0
2874 L70	118.6	114.0	112.0	105.0	112.0	109.0	106.0	99.0	93.0
2874 L80	114.5	109.0	107.0	102.0	109.0	106.0	101.0	95.0	92.0
2875 L40	126.1	121.0	121.0	114.0	120.0	114.0	108.0	101.0	102.0
2875 L50	125.3	120.0	121.0	114.0	118.0	113.0	107.0	102.0	97.0
2875 L60	122.0	116.0	115.0	111.0	117.0	112.0	107.0	102.0	100.0
2875 L70	119.8	112.0	112.0	108.0	115.0	112.0	109.0	102.0	95.0
2875 L80	116.3	108.0	108.0	104.0	112.0	109.0	105.0	99.0	93.0
2876 L40	130.7	126.0	124.0	118.0	125.0	120.0	115.0	109.0	107.0
2876 L50	129.7	123.0	124.0	119.0	124.0	120.0	116.0	111.0	105.0
2876 L60	126.5	119.0	120.0	115.0	122.0	117.0	113.0	108.0	103.0
2876 L70	124.1	114.0	115.0	112.0	120.0	117.0	114.0	107.0	101.0
2876 L80	120.1	110.0	111.0	108.0	116.0	113.0	110.0	104.0	98.0
2877 L40	132.2	126.0	126.0	120.0	127.0	123.0	116.0	111.0	112.0
2877 L50	132.8	126.0	126.0	122.0	128.0	123.0	115.0	114.0	105.0
2877 L60	129.2	121.0	122.0	119.0	125.0	120.0	116.0	111.0	107.0
2877 L70	126.7	116.0	116.0	114.0	123.0	120.0	117.0	110.0	103.0
2877 L80	122.6	112.0	112.0	111.0	118.0	117.0	112.0	107.0	103.0
2878 L40	134.1	129.0	129.0	122.0	127.0	123.0	118.0	113.0	113.0
2878 L50	134.2	127.0	128.0	124.0	129.0	124.0	121.0	117.0	112.0
2878 L60	130.8	123.0	124.0	120.0	126.0	122.0	118.0	114.0	111.0
2878 L70	128.5	118.0	119.0	117.0	124.0	122.0	119.0	113.0	107.0
2878 L80	124.2	113.0	114.0	112.0	120.0	118.0	114.0	105.0	105.0

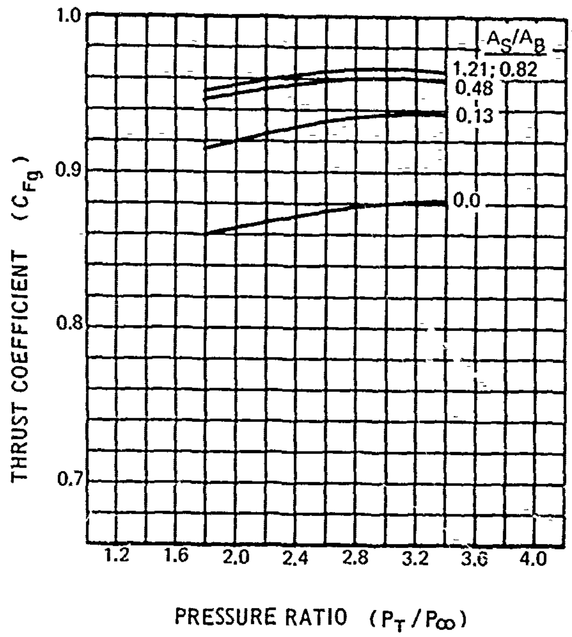
NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

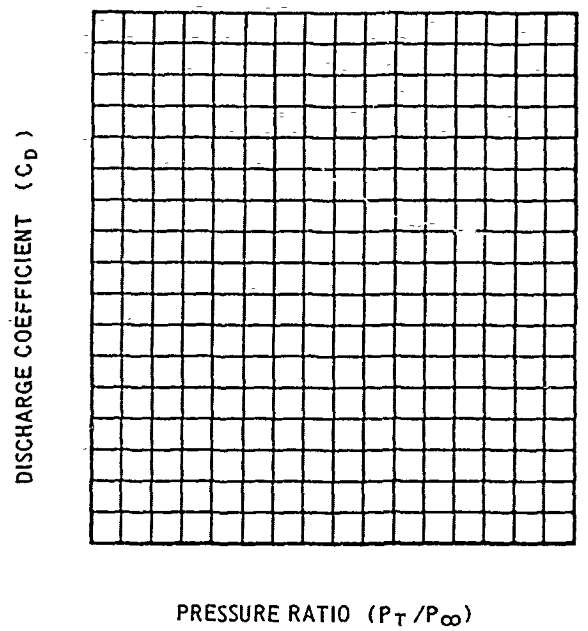
HM-AP-43

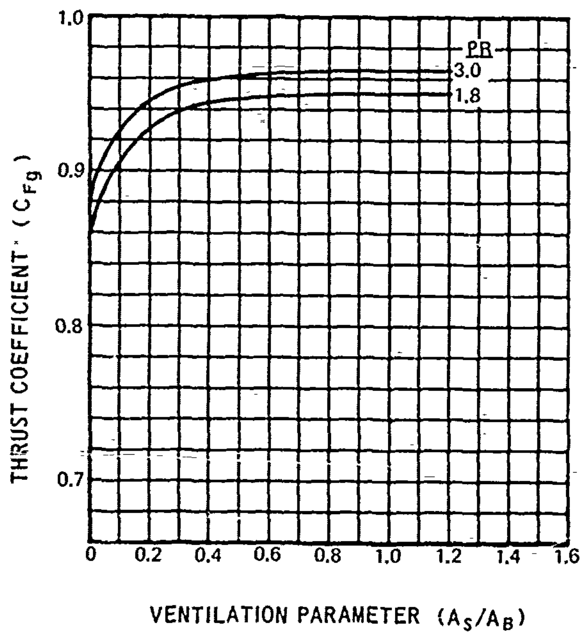


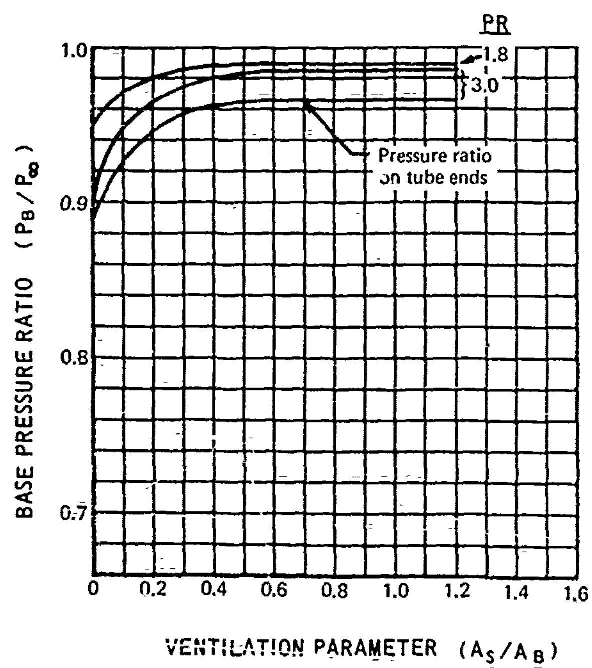
$$C_{F_g} = \frac{(\text{THRUST} - \text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



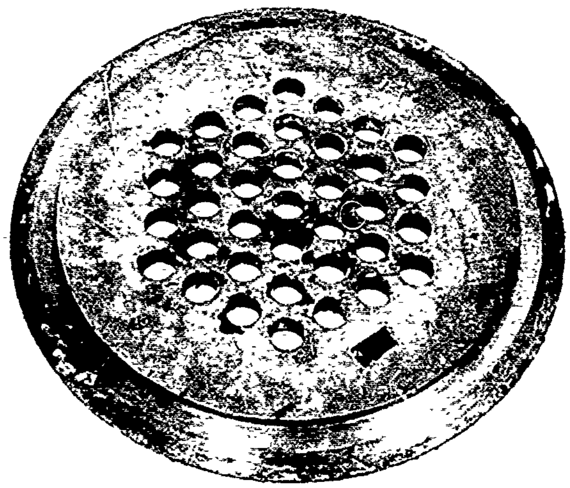






HM-AP-44 NOZZLE

(37 TUBE, HEXAGONAL ARRAY, AR 5.2



BASE PLATE WITH TUBES REMOVED

Description:

The HM-AP-44 nozzle is a hexagonal array of 37 tubes, equally spaced. The tubes have round convergent terminations. The tubes were inserted into a 17-inch diameter baseplate and were removeable.

Number of Elements: 37 tubes with round convergent ends

Area Ratio: 5.2

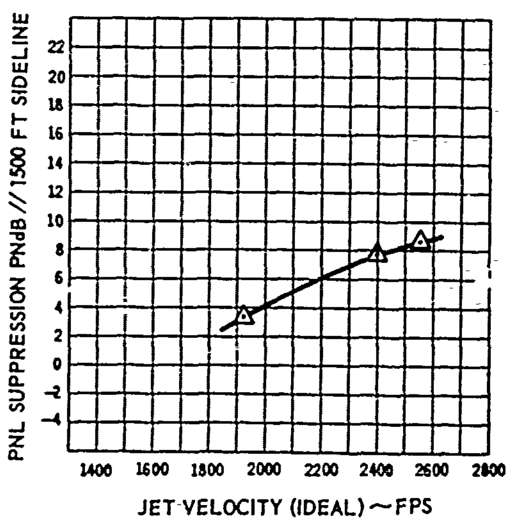
Flow Area: 13.2 square inches

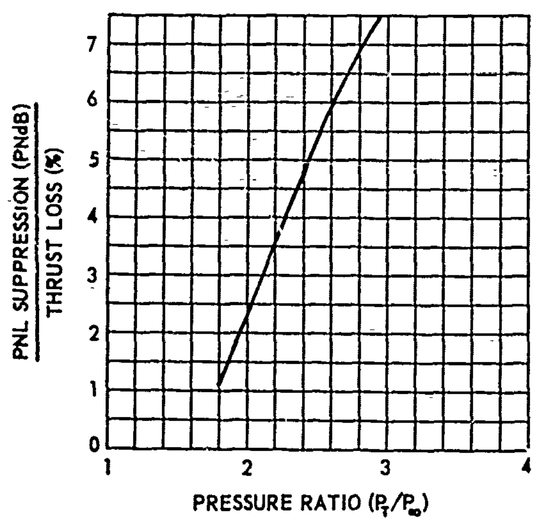
Exit Cant Angle: 0 degrees

Length of Tubes: 7 inches

Tube Exit Diameter: 0.674 inches

Material: 321 CRES



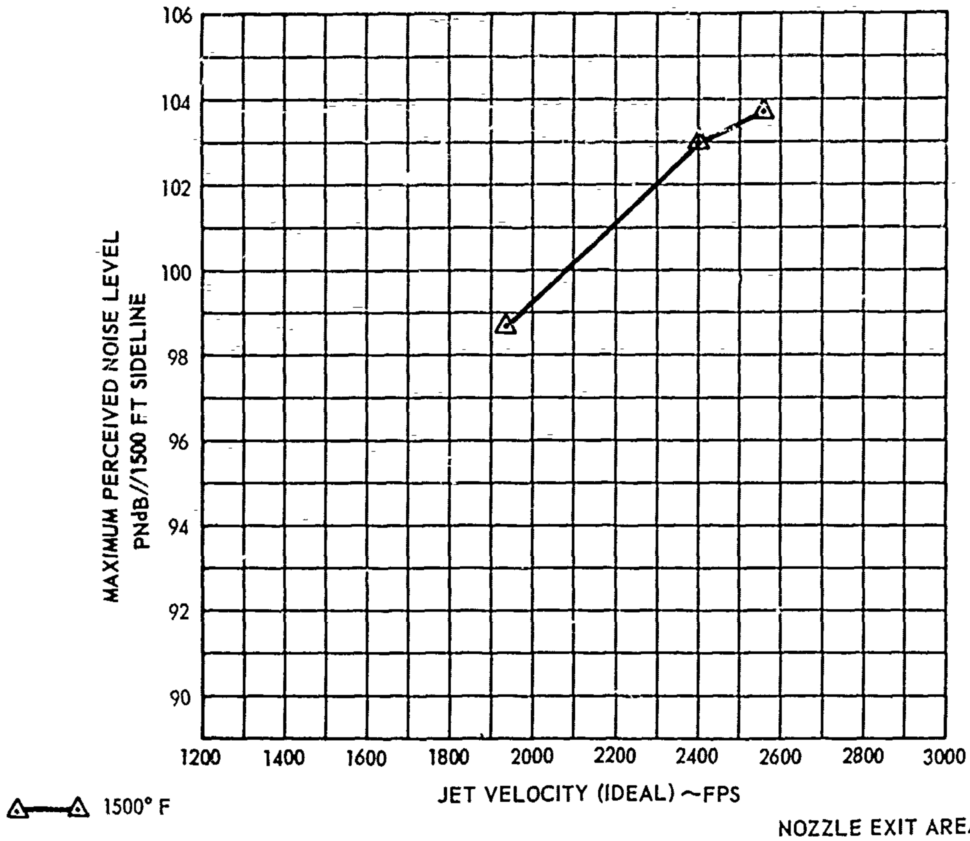


△—△ 1500° F

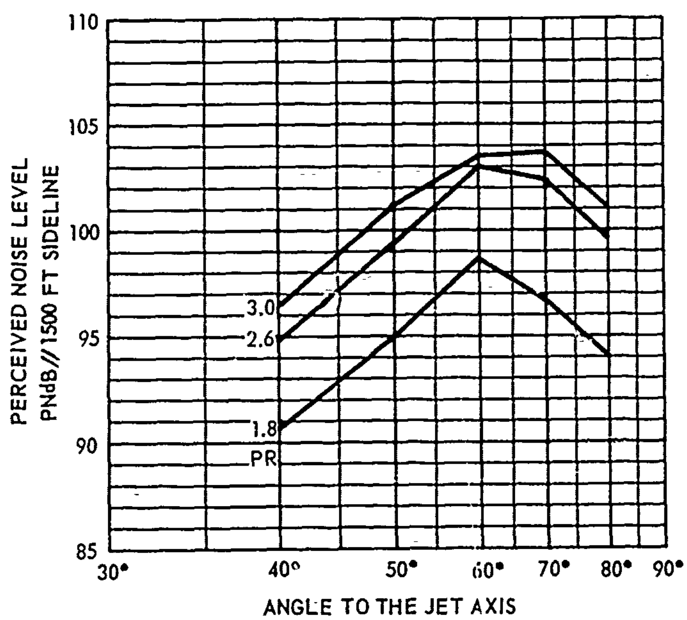
NOZZLE EXIT AREA (A_e): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-44 NOZZLE
(37 TUBE HEXAGONAL ARRAY)
AR 5.2
SCALE FACTOR: 8:1

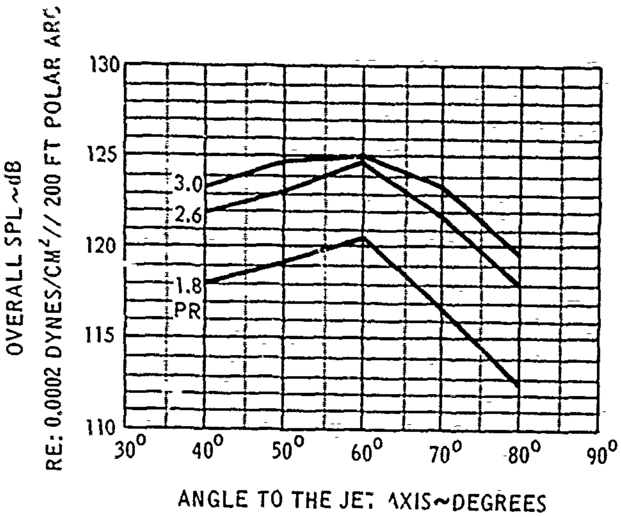


NOZZLE EXIT AREA (A_8): 5.9 FT^2

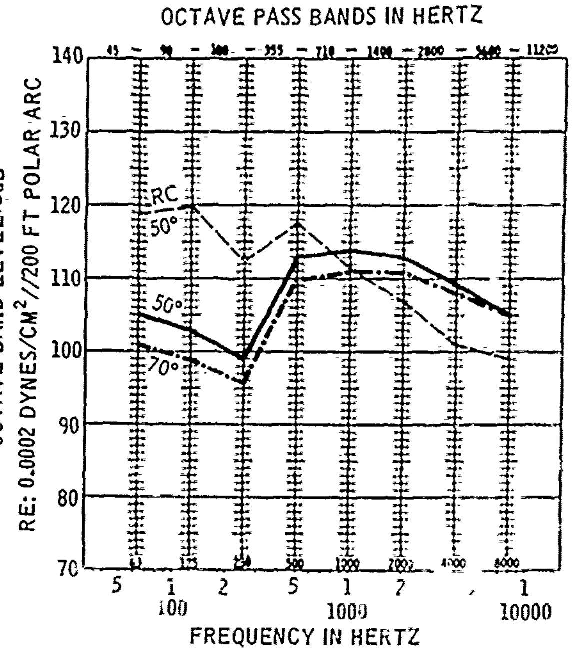


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

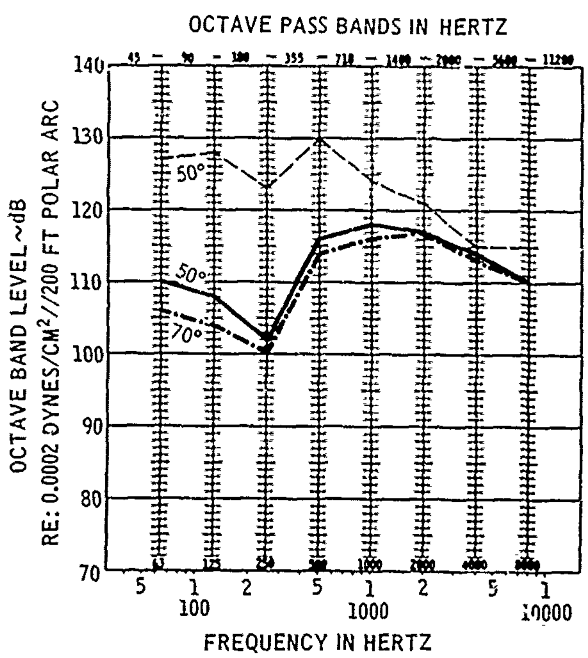


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

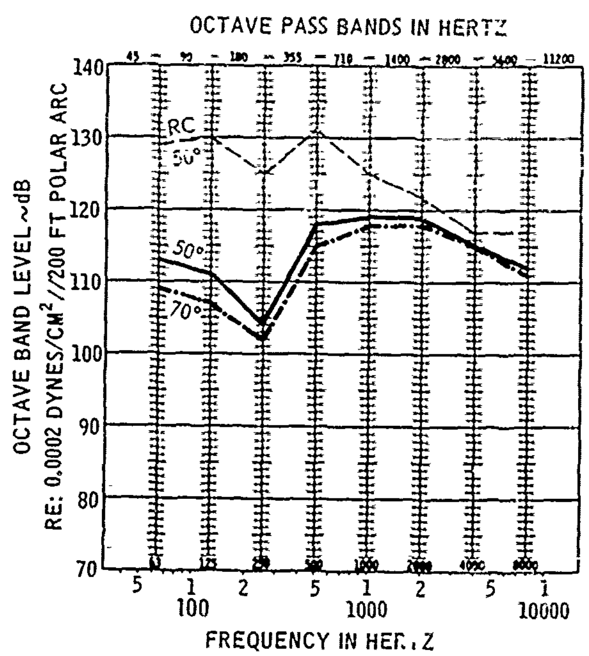


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

HM-AP-44 NOZZLE
(37 TUBE HEXAGONAL ARRAY)
AR 5.2
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2402 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-44 NOZZLE

(37 Tube Hexagonal Array, AR 5.2)

Remarks

The HM-AP-44 nozzle is one of a series of 37 tube hexagonal arrays to study the effect of area ratio on jet noise characteristics. The tubes in this series have round-convergent terminations. The HM-AP-44 nozzle was tested with various tube length configurations, e.g. 7, 5, 3 and 1 inches. Tube length had little effect on jet noise characteristics (Ref. D19). Nozzles in this test series were:

HM-AP-16	AR 3.33	(water cooled base plate)
HM-AP-37	AR 4.65	
HM-AP-38	AR 8.0	
HM-AP-39	AR 4.0	
HM-AP-43	AR 3.33	
HM-AP-44	AR 5.2	
HM-AP-55A	AR 4.0	(3000°F model)
HM-AP-55B	AR 5.2	" "
HM-AP-55C	AR 3.33	" "

HM-AP-44

Test Facility: Annex D (Cell #1)
Nozzle and microphone heights are 20 inches.

Date:

T_{amb}:

R. H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H1251	1.8	1500°F	1923 fps	HM-AP-44
H1252	2.6	"	2402	"
H1253	3.0	"	2555	"
H1227	1.8	1500°F	1923 fps	4.1 Inch Round Convergent Nozzle
H1228	2.6	"	2402	"
H1229	3.0	"	2555	"

Measured acoustic data is recorded in Reference D2.

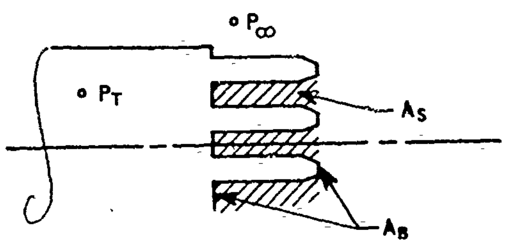
HM-AP-44 NOZZLE TEST DATA

OCTAVE BAND LEVEL ~ dB RE: 0.0002 DYNES/CM^2 // 25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H1227L40	123.7	118.1	119.9	111.7	116.5	109.2	104.9	98.3	96.6
H1227L50	124.2	118.7	119.6	112.5	117.5	111.3	107.1	100.8	99.4
H1227L60	121.6	114.8	114.8	109.7	116.7	112.6	108.5	103.4	98.2
H1227L70	120.3	111.6	112.6	107.6	116.5	111.5	108.5	103.4	100.3
H1227L80	116.2	107.9	107.9	104.9	111.9	107.9	104.9	100.9	95.9
H1228L40	134.4	128.0	130.0	123.0	128.0	122.0	119.0	114.0	113.0
H1228L50	134.4	127.0	128.0	123.0	130.0	124.0	121.0	115.0	115.0
H1228L60	130.2	121.0	123.0	119.0	126.0	122.0	118.0	114.0	109.0
H1228L70	127.9	117.0	119.0	116.0	124.0	120.0	118.0	113.0	110.0
H1228L80	123.1	113.0	113.0	111.0	119.0	116.0	113.0	110.0	105.0
H1229L40	135.4	130.0	131.0	124.0	128.0	123.0	119.0	114.0	113.0
H1229L50	136.0	129.0	130.0	125.0	131.0	125.0	122.0	117.0	117.0
H1229L60	132.1	123.0	124.0	121.0	128.0	124.0	120.0	116.0	112.0
H1229L70	129.8	119.0	120.0	118.0	126.0	122.0	120.0	116.0	113.0
H1229L80	125.6	115.0	115.0	114.0	121.0	119.0	116.0	113.0	108.0
H1251L40	118.0	104.0	102.0	98.0	112.0	113.0	112.0	107.0	103.0
H1251L50	119.1	105.0	103.0	99.0	113.0	114.0	113.0	109.0	105.0
H1251L60	120.6	104.0	101.0	98.0	114.0	116.0	115.0	110.0	105.0
H1251L70	116.7	101.0	99.0	96.0	110.0	111.0	111.0	108.0	105.0
H1251L80	112.7	99.0	96.0	93.0	106.0	106.0	107.0	105.0	100.0
H1252L40	122.0	109.0	107.0	103.0	115.0	117.0	116.0	112.0	108.0
H1252L50	123.1	110.0	108.0	102.0	116.0	118.0	117.0	114.0	110.0
H1252L60	124.7	109.0	107.0	103.0	118.0	120.0	119.0	114.0	110.0
H1252L70	121.8	106.0	104.0	100.0	114.0	116.0	117.0	113.0	110.0
H1252L80	118.0	104.0	100.0	97.0	110.0	111.0	113.0	111.0	106.0
H1253L40	123.4	112.0	109.0	104.0	117.0	118.0	117.0	113.0	109.0
H1253L50	124.8	113.0	111.0	104.0	118.0	119.0	119.0	115.0	112.0
H1253L60	125.0	112.0	110.0	105.0	118.0	120.0	119.0	115.0	110.0
H1253L70	123.4	109.0	107.0	102.0	115.0	118.0	118.0	115.0	111.0
H1253L80	119.5	106.0	103.0	100.0	111.0	113.0	114.0	113.0	107.0

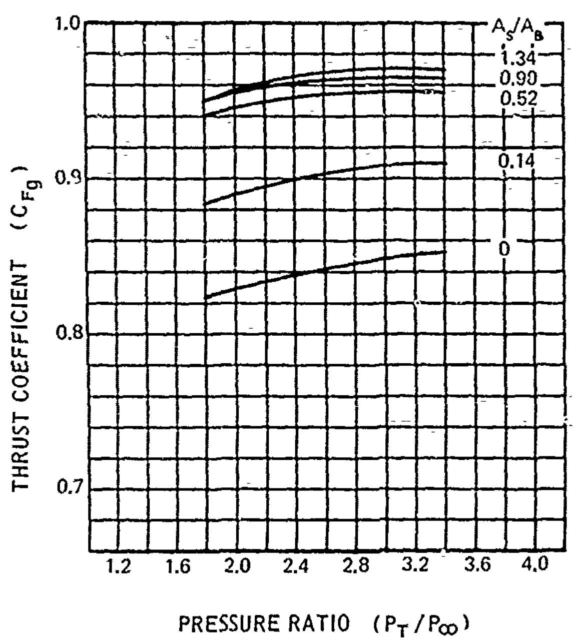
DATA INCLUDES GROUND REFLECTION INTERFERENCE

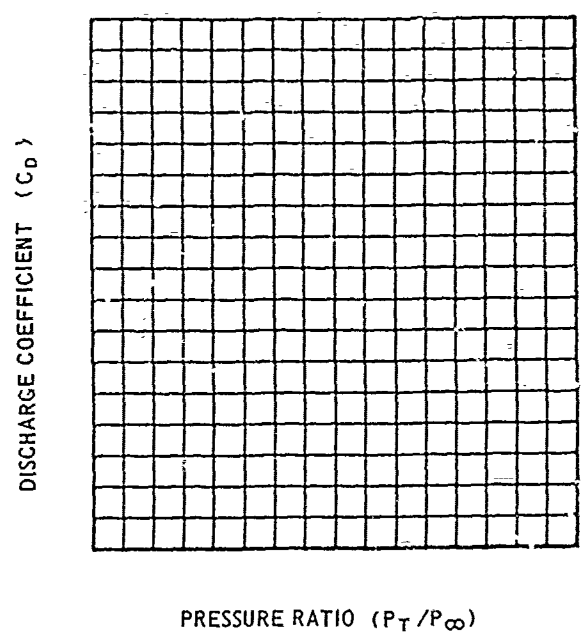
HM-AP-44

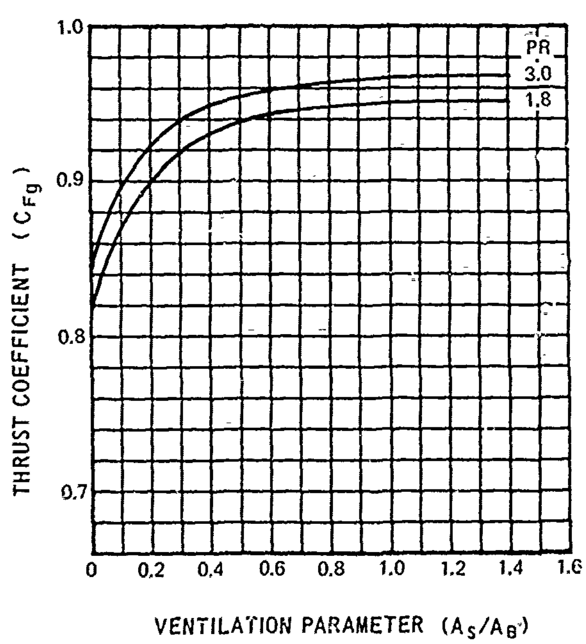


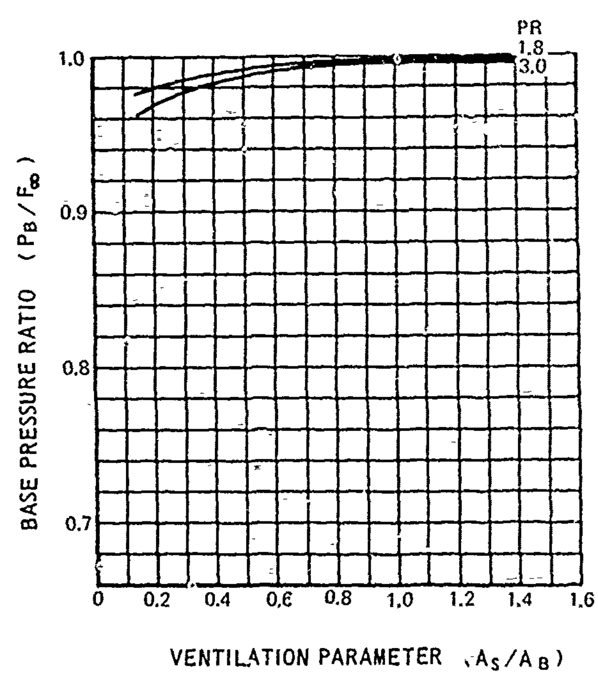
$$C_{Fg} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



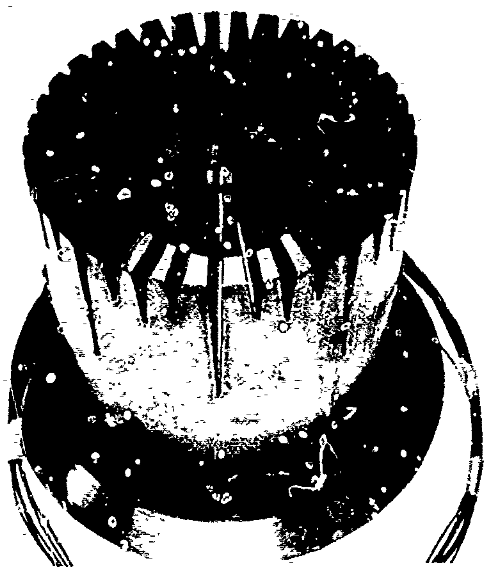






HM-AP-45 NOZZLE

(36 SPOKES, AR 2.06)



Description:

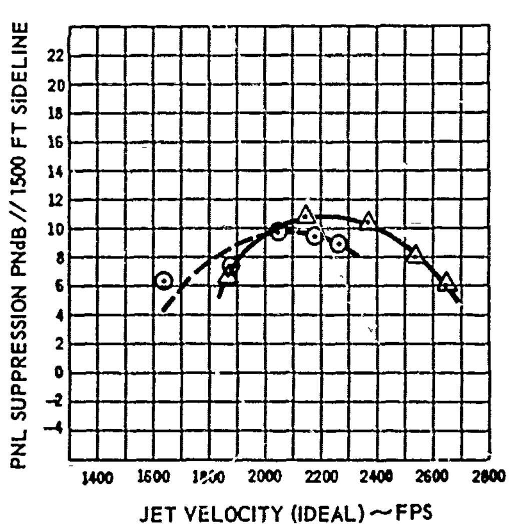
36 Spokes

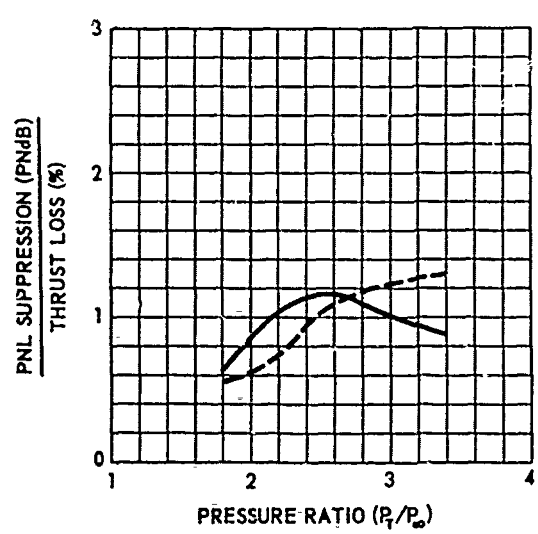
Area Ratio (A_T/A_P): 2.06

Spoke Penetration: Varies from 60% to 90%

Flow Area: 28.3 inches^2

Material: 321 CRES





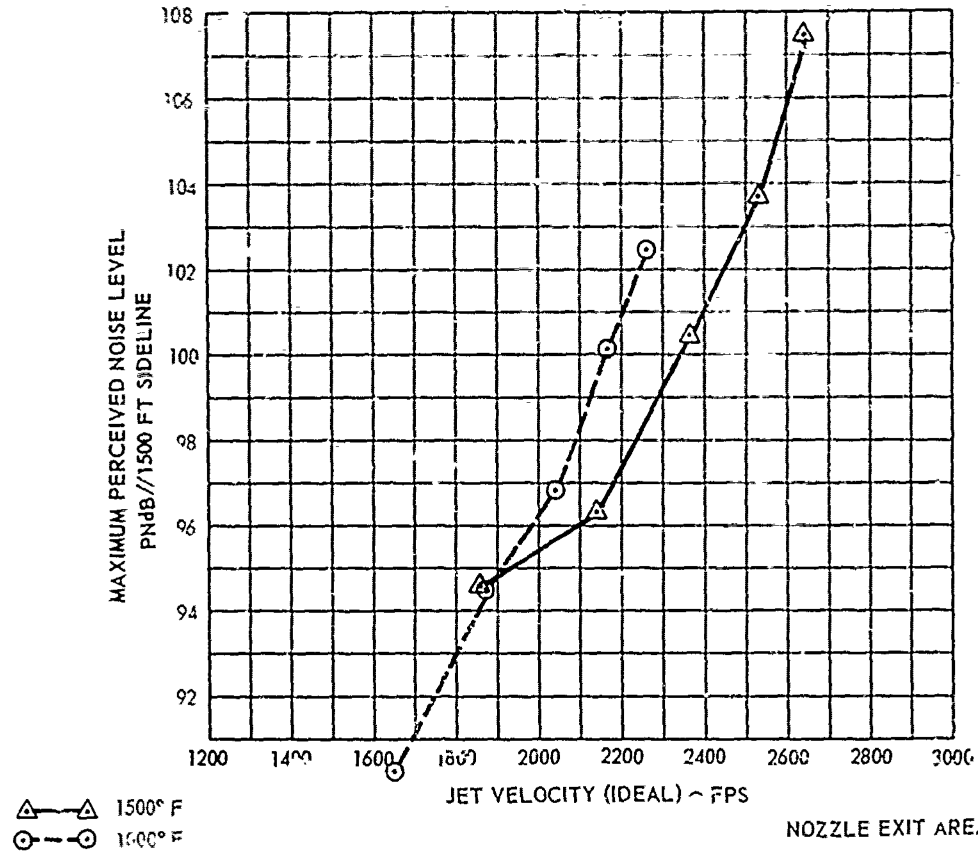
1500° F

1000° F

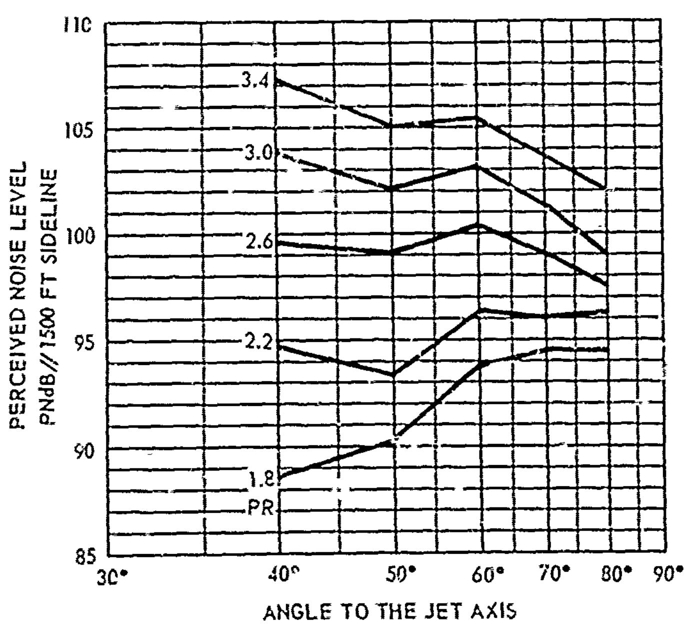
NOZZLE EXIT AREA (A_e): 12.6 FT^2

FREE FIELD VALUES

HM-AP-45 NOZZLE
(36 SPOKES)
AR 2.06
SCALE FACTOR: 8:1

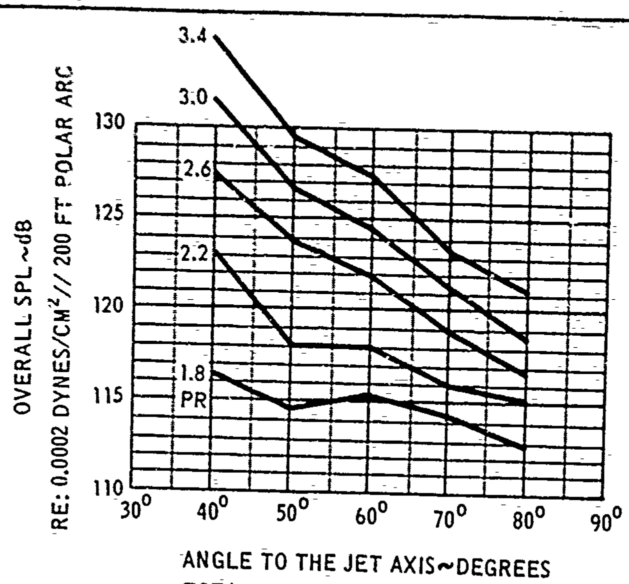


NOZZLE EXIT AREA (A_8): 12.6 FT^2

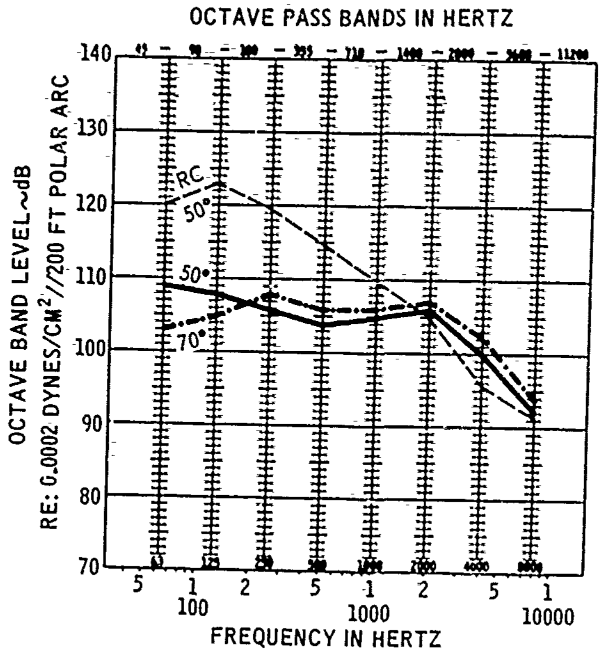


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT^2

FREE FIELD VALUES

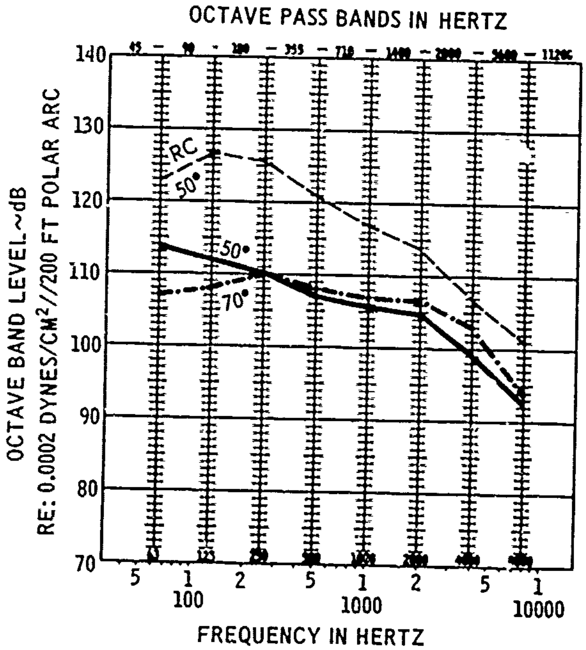


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT²

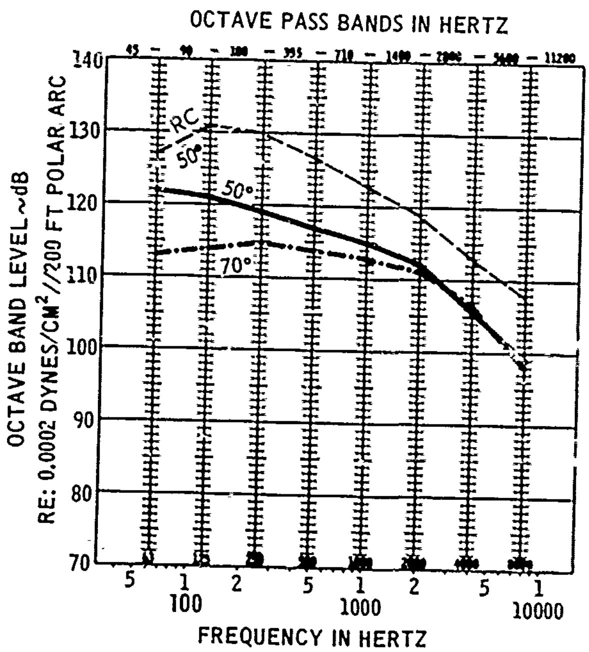


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1894 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²

HM-AP-45 NOZZLE
(36 SPOKES)
AR 2.06
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2169 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2521 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

HM-AP-45 NOZZLE

(36 Spokes, AR 2.06)

Remarks

The HM-AP-45 nozzle loses suppression rapidly as pressure ratio increases above 2.6. This shows up in a high rate of increase in low frequency noise as pressure ratio increases, considered to be generated by the merging of adjacent jet efflux. The individual jets tend to merge close to the exit plane where considerable kinetic energy is available in the flow, thus resulting in high values of shear, and turbulence, where the jets coalesce.

Other configurations of the HM-AP-45 nozzle included ejector installations. All ejectors were approximately 14-inches long (equivalent to 112-inches full scale). One ejector had an inside diameter to primary nozzle diameter (Ds/Dp) ratio of 1.2. The ejector was lined with fiber-glass batting for absorption of acoustic energy. This lined ejector resulted in 3 to 5 PNdB more suppression. Suppression in the last four octave bands was noted with the Ds/Dp = 1.2 lined ejector installed. When a hardwall ejector was installed only 2 to 3 PNdB additional suppression was evident.

A smaller ejector with a Ds/Dp = 1.0 was installed, a[illegible] No improvement was noted relative to the basic nozzle. See Reference D23. See Reference D24 for a comparison of model-scale and full-scale nozzle test results.

HM-AP-45 NOZZLE

Test Facility: HNTF

Date: July 15, 1968

T_{amb}: 72°F

R.H.: 37%

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
162.1	3.385	977°F	2269 fps	HM-AP-45
162.2	3.003	980	2173	"
162.3	2.597	972	2037	"
162.4	2.203	982	1880	"
162.5	1.801	977	1640	"
163.1	3.388	1471	2645	"
163.2	2.997	1463	2521	"
163.3	2.591	1458	2365	"
163.4	2.191	1459	2142	"
163.5	1.794	1412	1870	"
160.1	3.394	1468	2644	6-inch Round Convergent Nozzle
160.2	3.032	1451	2524	" " "
160.3	2.601	1458	2369	" " "
160.4	2.205	1461	2178	" " "
160.5	1.813	1462	1911	" " "
161.1	3.410	945	2248	" " "
161.2	2.993	944	2143	" " "
161.3	2.618	954	2032	" " "
161.4	2.210	950	1862	" " "
161.5	1.803	951	1626	" " "

HM-AP-45 NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
160.1L40	137.6	132.0	134.0	131.0	127.0	121.0	118.0	111.0	108.0
160.1L50	137.1	129.0	132.0	132.0	128.0	125.0	121.0	115.0	109.0
160.1L60	133.1	123.0	127.0	128.0	126.0	123.0	120.0	114.0	107.0
160.1L70	129.8	118.0	122.0	124.0	123.0	122.0	119.0	115.0	106.0
160.1L80	128.9	118.0	121.0	124.0	123.0	120.0	115.0	106.0	98.0
160.2L40	135.8	130.0	131.0	130.0	125.0	121.0	117.0	110.0	106.0
160.2L50	135.5	127.0	131.0	130.0	127.0	123.0	119.0	113.0	108.0
160.2L60	131.9	122.0	126.0	127.0	124.0	122.0	118.0	112.0	105.0
160.2L70	127.7	117.0	120.0	122.0	121.0	120.0	116.0	112.0	103.0
160.2L80	127.1	116.0	119.0	122.0	121.0	119.0	114.0	105.0	97.0
160.3L40	134.9	128.0	130.0	130.0	125.0	120.0	115.0	109.0	103.0
160.3L50	134.4	125.0	129.0	130.0	126.0	122.0	119.0	113.0	106.0
160.3L60	129.1	119.0	123.0	124.0	122.0	119.0	115.0	109.0	102.0
160.3L70	125.9	115.0	117.0	120.0	119.0	119.0	115.0	111.0	101.0
160.3L80	127.9	116.0	118.0	122.0	122.0	120.0	116.0	108.0	99.0
160.4L40	132.9	126.0	128.0	128.0	123.0	118.0	114.0	107.0	101.0
160.4L50	131.2	123.0	127.0	126.0	121.0	118.0	114.0	107.0	101.0
160.4L60	126.8	118.0	121.0	121.0	119.0	115.0	112.0	106.0	98.0
160.4L70	122.8	113.0	115.0	117.0	116.0	115.0	111.0	107.0	97.0
160.4L80	121.6	112.0	114.0	116.0	115.0	113.0	110.0	102.0	94.0
160.5L40	128.4	123.0	124.0	123.0	115.0	108.0	103.0	95.0	92.0
160.5L50	126.5	120.0	123.0	120.0	115.0	110.0	105.0	96.0	91.0
160.5L60	122.6	115.0	117.0	118.0	114.0	110.0	104.0	96.0	89.0
160.5L70	119.3	110.0	113.0	114.0	112.0	110.0	105.0	100.0	89.0
160.5L80	117.6	109.0	111.0	112.0	111.0	108.0	104.0	94.0	85.0
161.1L40	136.9	131.0	132.0	131.0	127.0	122.0	118.0	111.0	107.0
161.1L50	134.7	127.0	130.0	129.0	126.0	122.0	118.0	113.0	106.0
161.1L60	132.1	122.0	126.0	127.0	125.0	122.0	118.0	112.0	106.0
161.1L70	128.6	117.0	121.0	123.0	122.0	121.0	117.0	113.0	104.0
161.1L80	128.6	117.0	121.0	123.0	123.0	120.0	116.0	109.0	101.0
161.2L40	135.7	130.0	131.0	130.0	125.0	120.0	116.0	109.0	105.0
161.2L50	132.5	125.0	128.0	127.0	123.0	120.0	116.0	109.0	103.0
161.2L60	130.1	120.0	124.0	125.0	123.0	120.0	116.0	110.0	103.0
161.2L70	126.4	115.0	119.0	121.0	120.0	118.0	114.0	110.0	100.0
161.2L80	126.9	116.0	119.0	122.0	121.0	118.0	113.0	105.0	96.0
161.3L40	133.8	127.0	129.0	129.0	123.0	113.0	114.0	106.0	102.0
161.3L50	129.5	122.0	125.0	124.0	120.0	116.0	112.0	105.0	99.0
161.3L60	126.7	117.0	120.0	122.0	119.0	117.0	113.0	106.0	98.0
161.3L70	122.9	112.0	115.0	117.0	117.0	115.0	110.0	106.0	96.0
161.3L80	122.8	111.0	113.0	117.0	118.0	115.0	110.0	102.0	93.0
161.4L40	130.2	124.0	126.0	125.0	118.0	112.0	107.0	100.0	96.0
161.4L50	125.2	119.0	121.0	119.0	115.0	111.0	106.0	98.0	91.0
161.4L60	123.2	115.0	116.0	118.0	115.0	112.0	107.0	99.0	92.0
161.4L70	119.4	110.0	113.0	114.0	112.0	110.0	106.0	101.0	90.0
161.4L80	118.6	109.0	112.0	113.0	112.0	110.0	105.0	96.0	86.0
161.5L40	124.5	120.0	121.0	116.0	110.0	104.0	99.0	90.0	88.0
161.5L50	120.8	115.0	117.0	114.0	110.0	105.0	100.0	92.0	87.0
161.5L60	119.2	111.0	114.0	114.0	111.0	107.0	102.0	94.0	86.0
161.5L70	115.3	107.0	109.0	110.0	108.0	105.0	101.0	96.0	84.0
161.5L80	114.4	106.0	108.0	109.0	107.0	105.0	100.0	91.0	82.0

NOTE: THESE ARE FREE FIELD VALUES

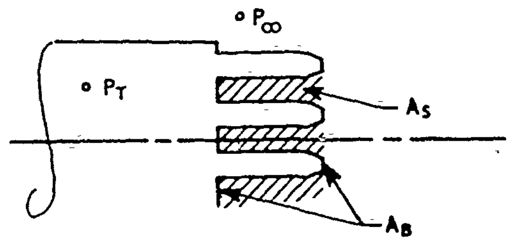
D198

HM-AP-45 NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
162.1L40	130.5	127.0	126.0	121.0	118.0	114.0	110.0	103.0	98.0
162.1L50	125.3	120.0	120.0	118.0	116.0	114.0	110.0	104.0	97.0
162.1L60	123.9	116.0	118.0	118.0	116.0	114.0	111.0	105.0	97.0
162.1L70	120.2	112.0	113.0	114.0	112.0	112.0	109.0	106.0	97.0
162.1L80	118.6	112.0	111.0	111.0	111.0	110.0	108.0	102.0	93.0
162.2L40	128.1	125.0	123.0	118.0	116.0	113.0	110.0	104.0	98.0
162.2L50	122.7	118.0	117.0	115.0	113.0	111.0	109.0	104.0	97.0
162.2L60	121.5	114.0	115.0	115.0	114.0	112.0	110.0	104.0	98.0
162.2L70	118.5	111.0	111.0	112.0	110.0	110.0	108.0	105.0	98.0
162.2L80	116.4	110.0	108.0	109.0	109.0	108.0	106.0	100.0	93.0
162.3L40	123.8	121.0	118.0	113.0	111.0	110.0	108.0	101.0	95.0
162.3L50	119.0	114.0	113.0	111.0	110.0	103.0	106.0	100.0	87.0
162.3L60	118.6	111.0	112.0	113.0	110.0	109.0	106.0	101.0	93.0
162.3L70	115.9	107.0	108.0	109.0	108.0	108.0	106.0	104.0	95.0
162.3L80	114.1	107.0	106.0	107.0	106.0	105.0	105.0	98.0	91.0
162.4L40	119.8	117.0	113.0	109.0	107.0	107.0	107.0	101.0	95.0
162.4L50	115.8	110.0	109.0	108.0	106.0	106.0	106.0	101.0	93.0
162.4L60	116.9	108.0	110.0	111.0	108.0	108.0	107.0	103.0	95.0
162.4L70	114.8	104.0	106.0	108.0	106.0	107.0	107.0	105.0	96.0
162.4L80	112.5	105.0	103.0	105.0	105.0	105.0	104.0	98.0	91.0
162.5L40	113.5	111.0	106.0	103.0	101.0	101.0	101.0	93.0	85.0
162.5L50	110.8	105.0	105.0	103.0	101.0	101.0	100.0	93.0	84.0
162.5L60	112.3	104.0	106.0	107.0	103.0	102.0	102.0	95.0	87.0
162.5L70	110.2	101.0	103.0	104.0	101.0	102.0	101.0	97.0	86.0
162.5L80	108.2	101.0	100.0	101.0	100.0	100.0	100.0	91.0	82.0
163.1L40	135.1	130.0	131.0	128.0	123.0	119.0	115.0	109.0	104.0
163.1L50	129.6	124.0	125.0	122.0	120.0	118.0	114.0	108.0	102.0
163.1L60	127.1	119.0	121.0	121.0	119.0	118.0	114.0	109.0	102.0
163.1L70	123.4	114.0	116.0	117.0	116.0	115.0	113.0	110.0	100.0
163.1L80	121.3	114.0	113.0	115.0	114.0	113.0	110.0	103.0	95.0
163.2L40	131.7	128.0	127.0	123.0	120.0	116.0	112.0	105.0	100.0
163.2L50	126.7	122.0	121.0	119.0	117.0	115.0	112.0	106.0	99.0
163.2L60	124.7	117.0	118.0	119.0	117.0	115.0	112.0	107.0	99.0
163.2L70	121.5	113.0	114.0	115.0	114.0	113.0	111.0	107.0	98.0
163.2L80	118.6	112.0	111.0	112.0	111.0	110.0	107.0	100.0	92.0
163.3L40	127.7	125.0	122.0	117.0	115.0	113.0	111.0	104.0	98.0
163.3L50	123.7	119.0	118.0	115.0	114.0	113.0	110.0	104.0	97.0
163.3L60	122.0	114.0	115.0	116.0	114.0	113.0	111.0	105.0	98.0
163.3L70	118.9	110.0	111.0	113.0	111.0	111.0	108.0	105.0	96.0
163.3L80	116.8	109.0	109.0	110.0	109.0	109.0	107.0	100.0	92.0
163.4L40	123.2	121.0	117.0	111.0	109.0	107.0	106.0	100.0	94.0
163.4L50	118.1	114.0	112.0	110.0	107.0	105.0	105.0	99.0	92.0
163.4L60	118.0	111.0	112.0	112.0	109.0	108.0	106.0	100.0	92.0
163.4L70	116.0	107.0	108.0	110.0	108.0	107.0	107.0	103.0	93.0
163.4L80	115.2	108.0	106.0	108.0	107.0	107.0	107.0	100.0	93.0
163.5L40	116.6	114.0	109.0	105.0	104.0	104.0	105.0	98.0	92.0
163.5L50	114.6	109.0	108.0	106.0	104.0	105.0	106.0	100.0	92.0
163.5L60	115.4	107.0	108.0	110.0	106.0	106.0	106.0	100.0	93.0
163.5L70	114.3	103.0	105.0	108.0	106.0	106.0	107.0	103.0	94.0
163.5L80	112.9	104.0	103.0	105.0	104.0	105.0	107.0	99.0	93.0

NOTE: THESE ARE FREE FIELD VALUES

HM - AP - 45 NO EJECTOR

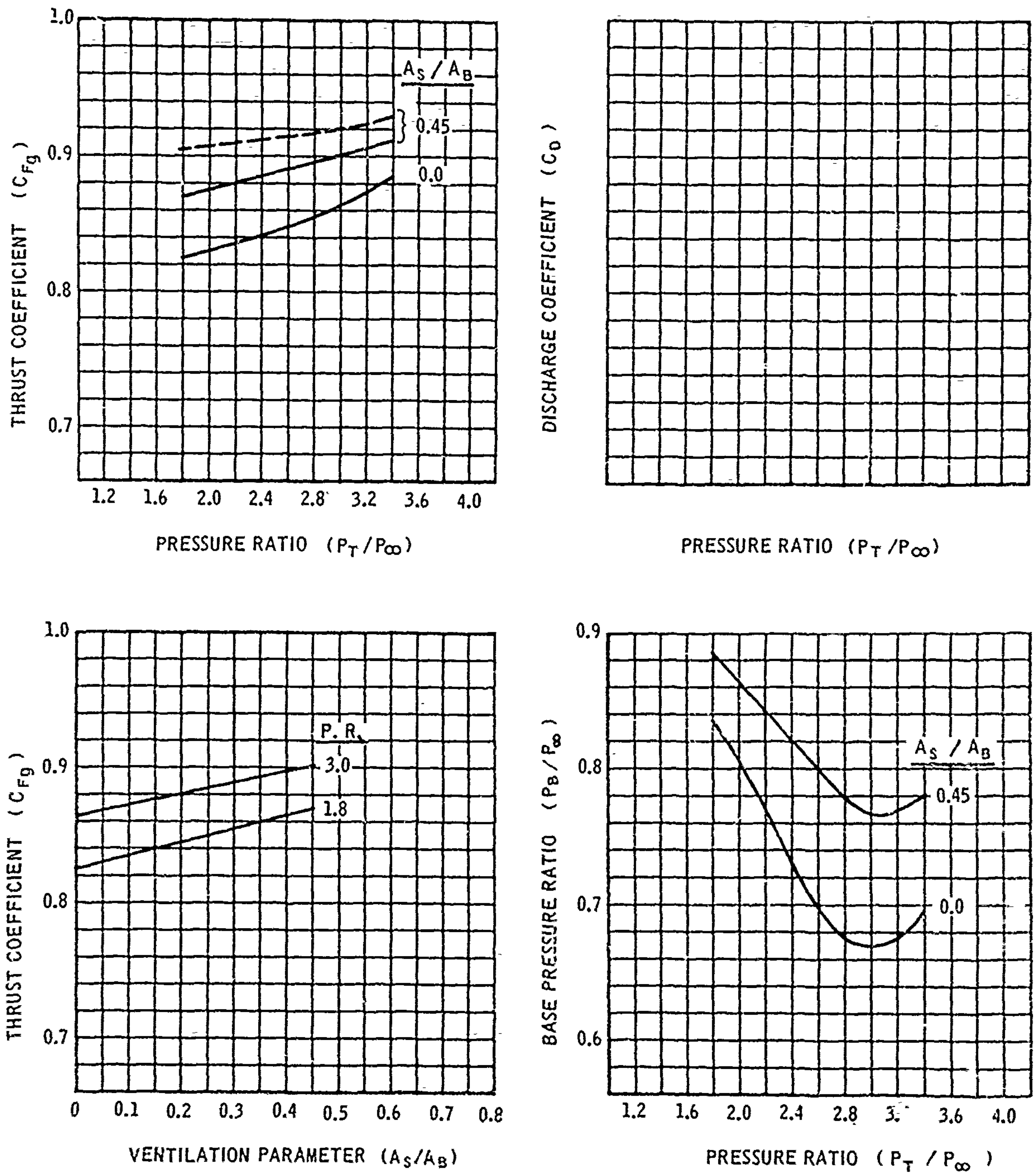


—— MODIFIED CONFIGURATION

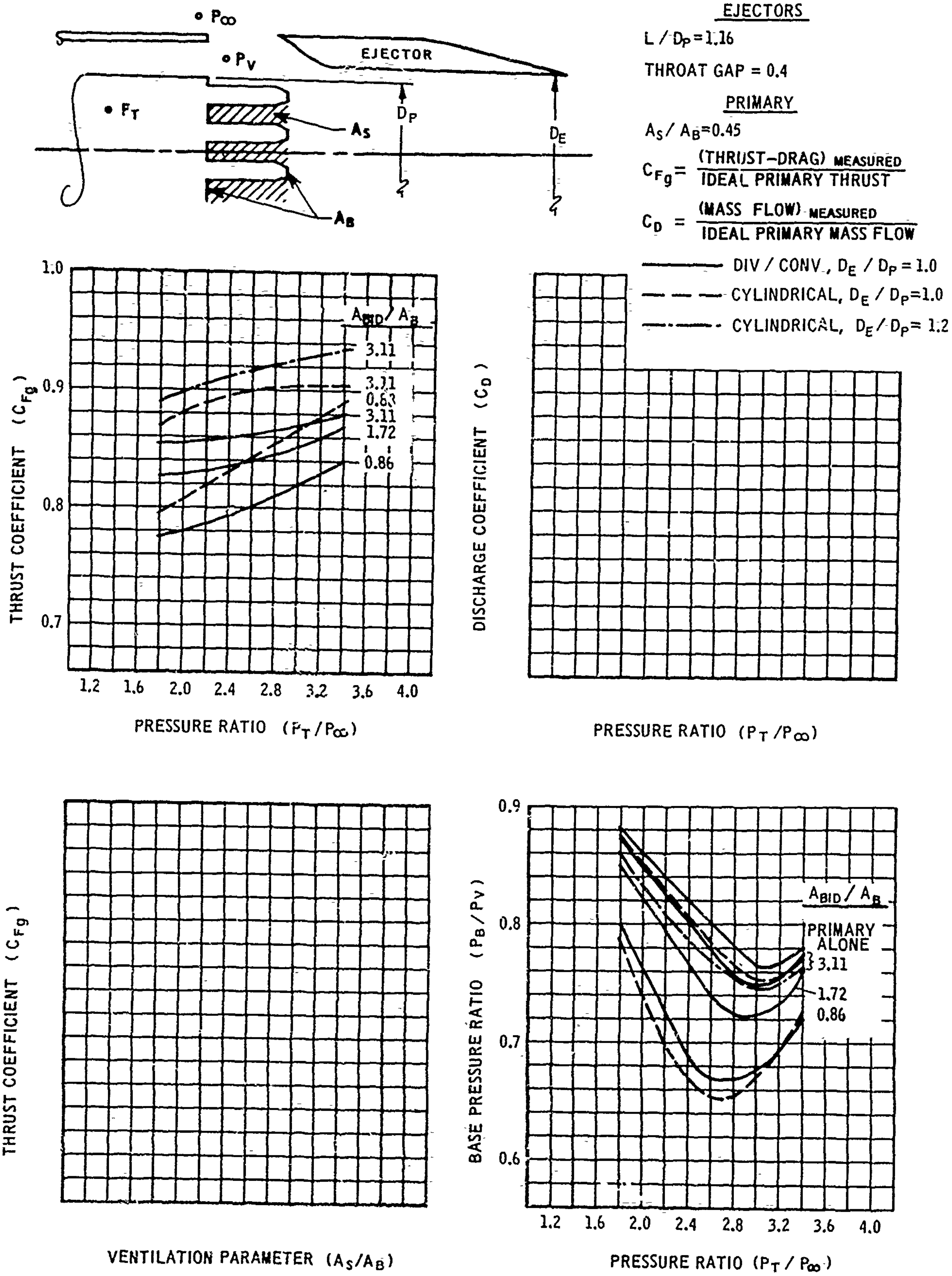
— — — ORIGINAL DESIGN

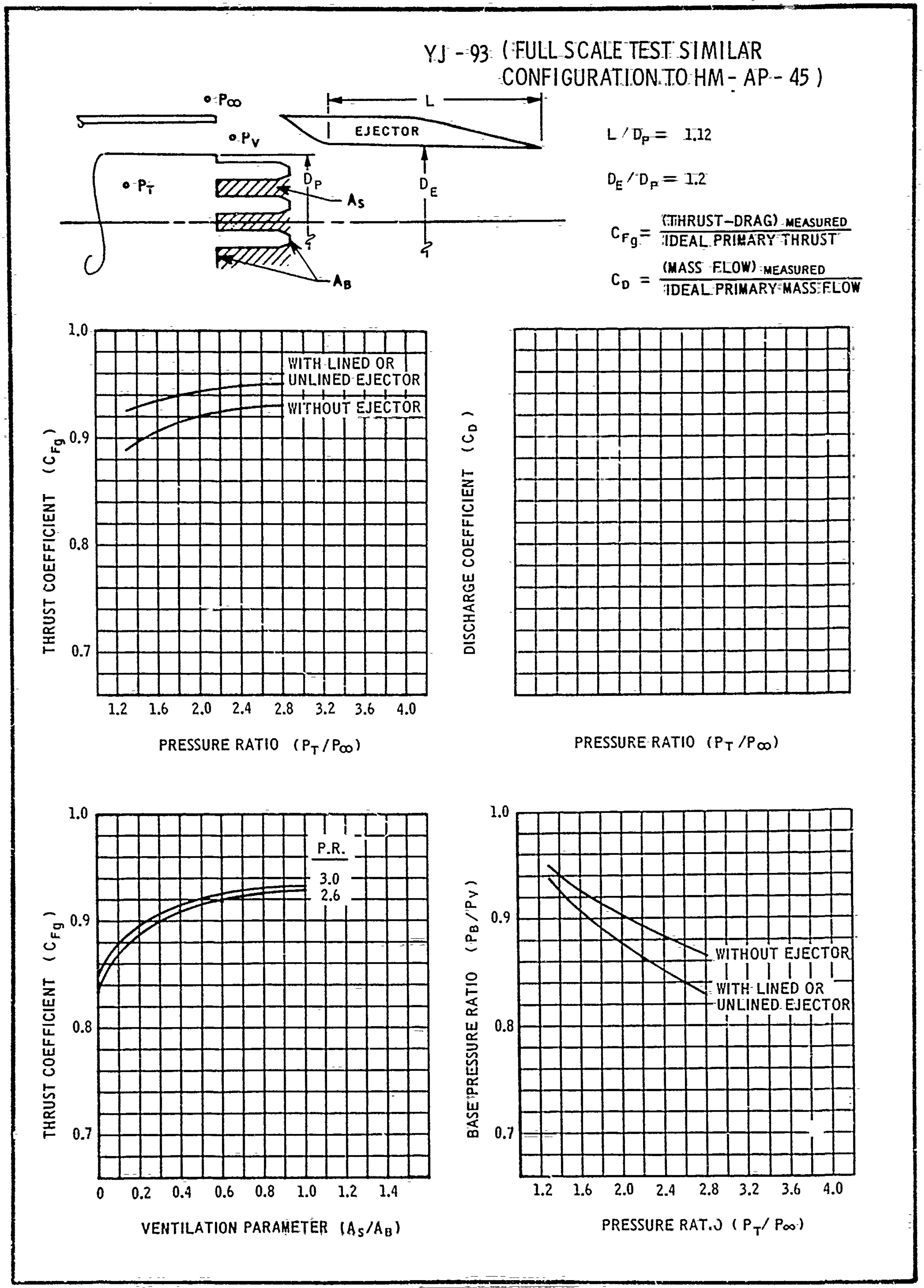
$$C_{Fg} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$

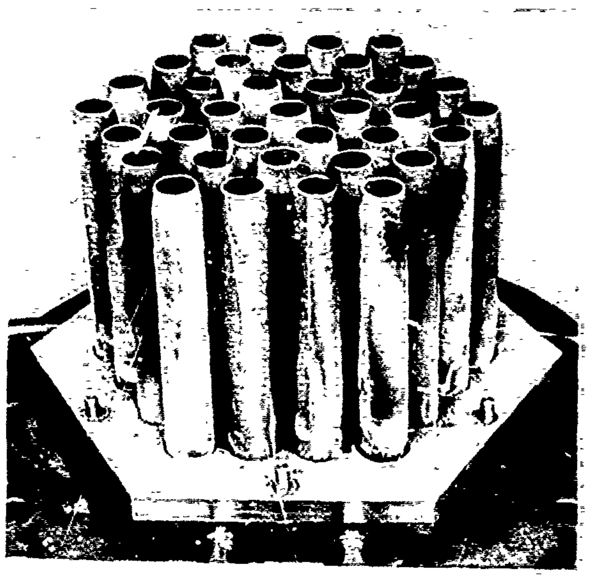


HM-AP-45 WITH EJECTORS




YJ - 93 (FULL SCALE TEST SIMILAR CONFIGURATION TO HM - AP - 45)
P_∞
P_V
P_T
L
EJECTOR
D_P
D_E
A_S
A_B
$L / D_P = 1.12$
$D_E / D_P = 1.2$
$C_{Fg} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$
$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$
THRUST COEFFICIENT (C_{Fg})
WITH LINED OR UNLINED EJECTOR
WITHOUT EJECTOR
1.0
0.9
0.8
0.7
1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0
PRESSURE RATIO (P_T / P_∞)
DISCHARGE COEFFICIENT (C_D)
PRESSURE RATIO (P_T / P_∞)
THRUST COEFFICIENT (C_{Fg})
P.R.
3.0
2.6
0 0.2 0.4 0.6 0.8 1.0 1.2 1.4
VENTILATION PARAMETER (A_S/A_B)
BASE PRESSURE RATIO (P_B/P_V)
WITHOUT EJECTOR
WITH LINED OR UNLINED EJECTOR
PRESSURE RATIO (P_T/P_∞)

HM-AP-55-C NOZZLE
(37 TUBE HEXAGONAL ARRAY, AR 3.33)



Description:

The HM-AP-55-C nozzle is a 37-tube, area ratio 3.33 nozzle intended for the acquisition of acoustic and performance data at gas total temperatures up to 3000°F. The tubes were fabricated from columbium material and coated with Cr-Ti-Si to resist oxidation at high temperatures. The tubes were inserted into a water-cooled baseplate and were removable.

Number of Elements: 37 tubes coated with round convergent ends

Area Ratio: 3.33

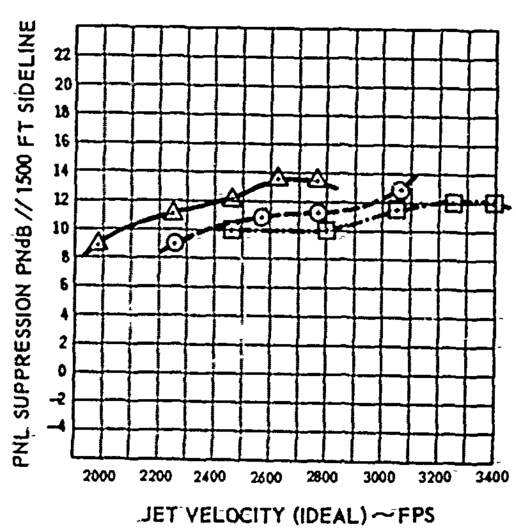
Flow Area: 13.2 square inches

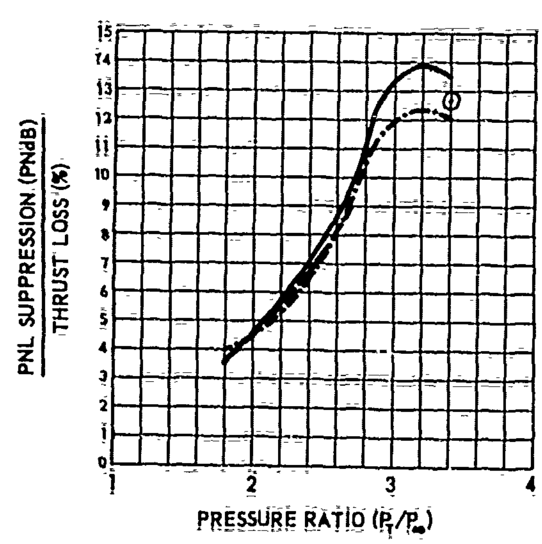
Exit Cant Angle: 0 degrees

Length of Tubes: 5.29 inches (effective)

Tube Exit Diameter: 0.674 inches

Material: Cr-Ti-Si coated columbium (tubes)

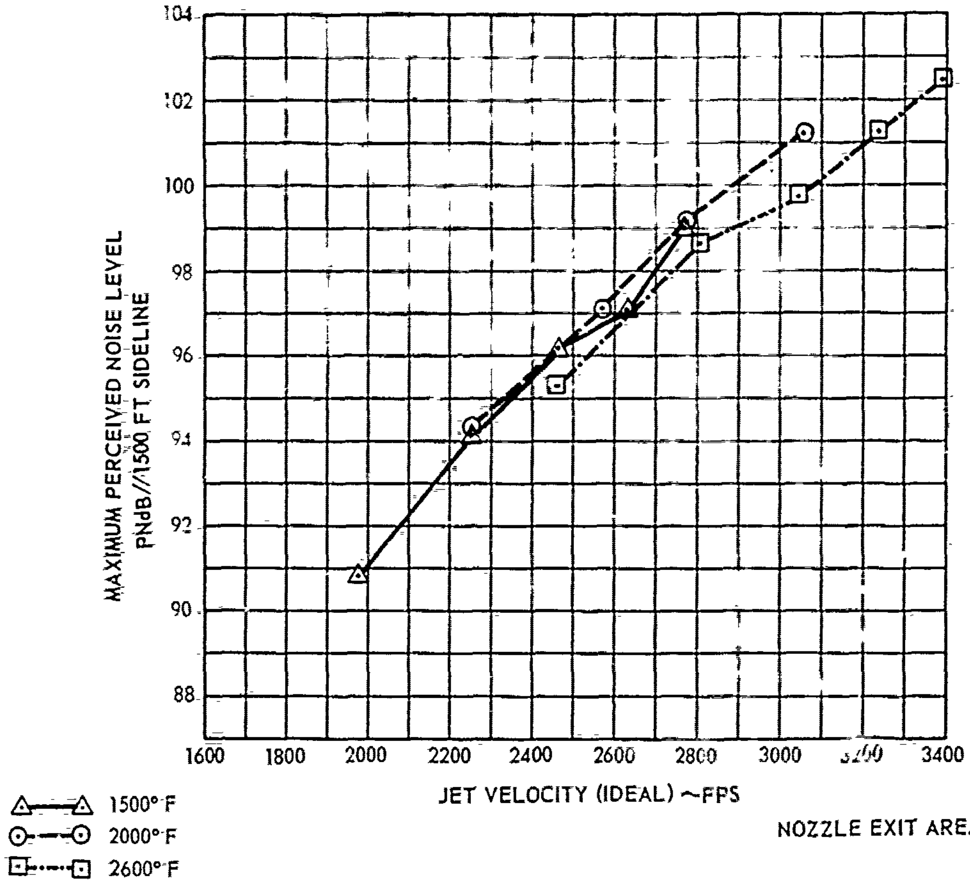




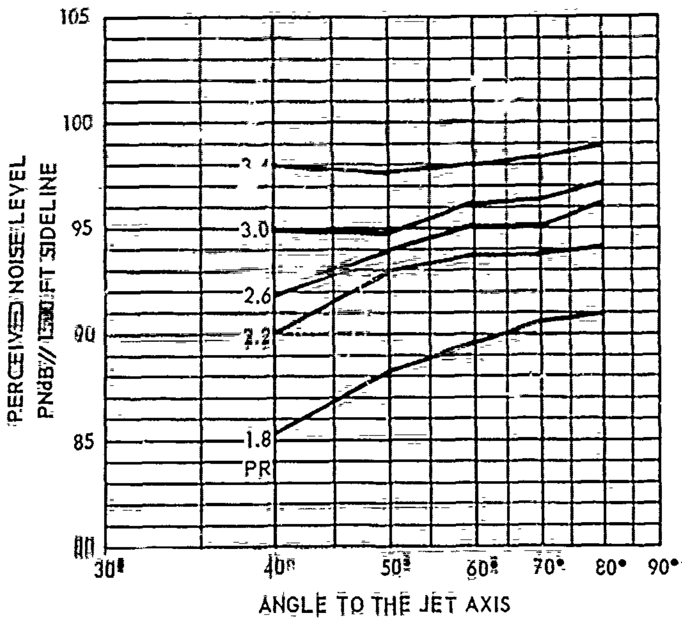
△——△ 1500° F
⊙---⊙ 2000° F
⊡····⊡ 2600° F

NOZZLE EXIT AREA (A_e): 5.9 FT^2
FREE FIELD VALUES

HM-AP-55-C NOZZLE
(37 TUBE HEXAGONAL ARRAY)
AR 3.33
SCALE FACTOR: 8:1

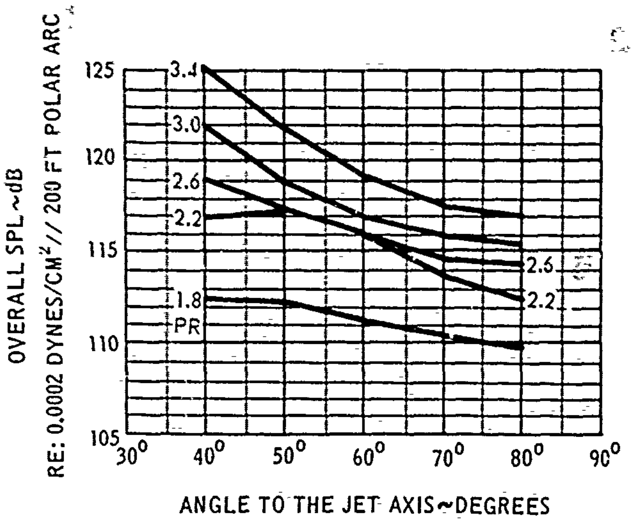


NOZZLE EXIT AREA (A_8): 5.9 FT^2

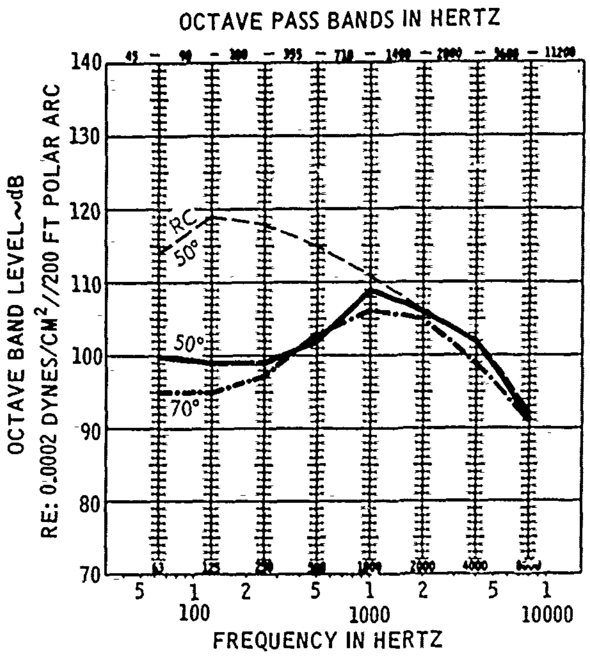


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT^2

FREE FIELD VALUES

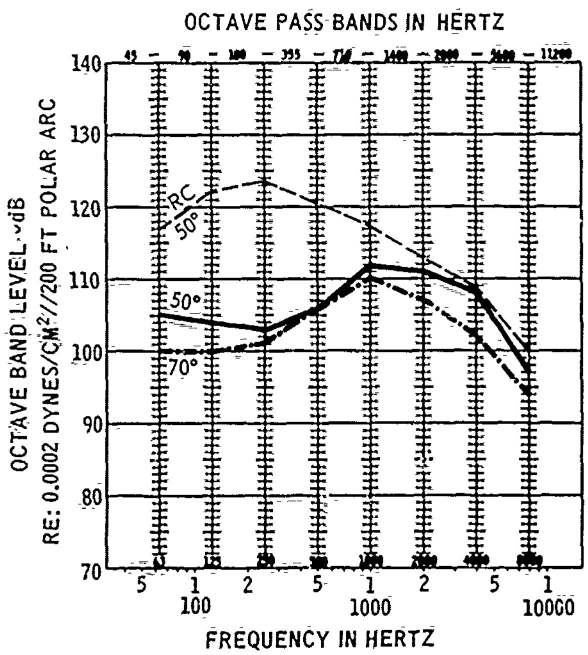


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT²

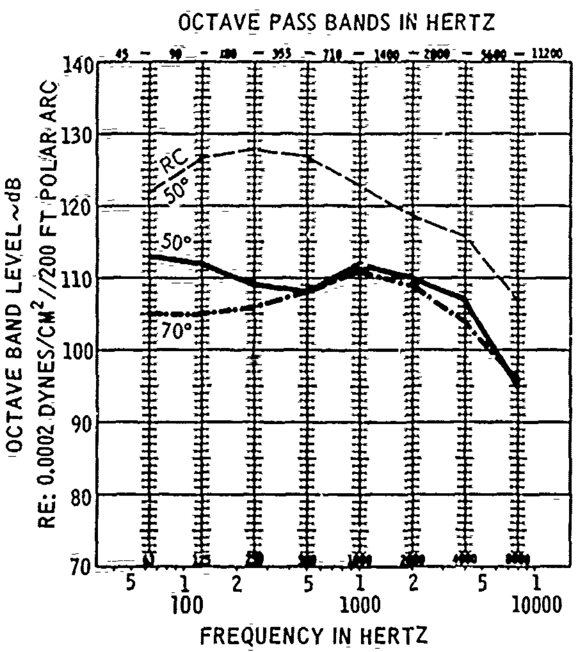


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1983 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

HM-AP-55-C NOZZLE
(37 TUBE HEXAGONAL ARRAY)
AR 3.33
SCALE FACTOR: 8 : 1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2255 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2626 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

FREE FIELD VALUES

HM-AP-55-C NOZZLE

(37 Tube Hexagonal Array, AR = 3.33)

Remarks

This nozzle was designed to extend the multitube parametric study in the high jet velocity and total temperature ($\geq$ 3000°F) regions common to afterburning turbojet engines. Tests were conducted at the HNTF, Reference D25, and the GE JENOTS facility, Reference D26. The acoustic data acquired in either case indicated that instrumentation and facility problems existed at the high gas temperatures.

Higher suppression values, about 2 PNdB, were reported in Reference D26. Differences in temperature profile may have been responsible.

Three high temperature nozzle configurations were intended for this series:

HM-AP-55-A (37 Tubes, AR 4.0)
HM-AP-55-B (37 Tubes, AR 5.2)
HM-AP-55-C (37 Tubes, AR 3.33)

HM-AP-55-C NOZZLE

Test Facility: HNTF

Date: August 13, 1968

T_{amb}: 67°F

R. H.: 75%

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
222.1	1.82	1568°F	1983 fps	HM-AP-55C
222.2	2.22	1562	2255	"
222.3	2.63	1574	2463	"
222.4	3.04	1589	2626	"
222.5	3.44	1623	2768	"
223.1	1.81	2612	2454	"
223.2	2.24	2722	2874	"
223.3	2.64	2706	3110	"
223.4	3.03	2712	3299	"
223.5	3.44	2680	3435	"
224.3	1.81	2158	2260	"
224.4	2.23	2134	2570	"
224.5	2.63	2081	2771	"
224.6	3.03	2090	2942	"
224.7	3.44	2058	3062	"
225.1	1.82	2621	2460	"
225.2	2.23	2585	2802	"
225.3	2.63	2582	3044	"
225.4	3.04	2596	3238	"
225.5	3.44	2707	3390	"
218.1	1.84	2677°F	2477 fps	4.1 Inch Round Convergent Nozzle
218.2	2.22	2753	2847	"
218.3	2.63	2768	3119	"
218.4	3.03	2762	3304	"
218.5	3.43	2893	3502	"
219.1	1.82	1681	2026	"
219.2	2.23	1704	2329	"
219.3	2.63	1676	2575	"
219.4	3.04	1702	2690	"
219.5	3.44	1641	2768	"
220.1	1.82	2121	2223	"
220.2	2.23	2133	2550	"

HM-AP-55-C NOZZLE

220.3	2.64	2089	2758	4.1 Inch Round Convergent Noz.
220.4	3.05	2051	2912	"
220.5	3.44	2044	3040	"
221.1	1.82	2679	2468	"
221.2	2.23	2665	2809	"
221.3	2.62	2540	3044	"
221.4	3.04	2515	3230	"
221.5	3.44	2546	3347	"

HM-AP-55-C NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
218.1L40	126.8	120.0	121.0	122.0	118.0	113.0	109.0	101.0	95.0
218.1L50	127.4	117.0	122.0	122.0	120.0	117.0	113.0	108.0	99.0
218.1L60	126.9	114.0	120.0	123.0	120.0	116.0	113.0	105.0	97.0
218.1L70	120.7	109.0	112.0	115.0	115.0	113.0	109.0	103.0	93.0
217.1L80	118.3	107.0	109.0	112.0	113.0	111.0	107.0	100.0	89.0
218.2L40	128.6	122.0	124.0	123.0	119.0	115.0	110.0	103.0	96.0
218.2L50	129.5	120.0	124.0	125.0	121.0	118.0	114.0	110.0	101.0
218.2L60	130.3	116.0	122.0	126.0	125.0	120.0	117.0	111.0	104.0
218.2L70	123.9	111.0	115.0	118.0	118.0	117.0	113.0	108.0	100.0
218.2L80	122.4	110.0	112.0	115.0	117.0	116.0	113.0	106.0	97.0
218.3L40	130.4	125.0	125.0	125.0	120.0	115.0	111.0	103.0	98.0
218.3L50	131.8	122.0	127.0	127.0	123.0	120.0	116.0	112.0	104.0
218.3L60	133.4	119.0	125.0	129.0	128.0	124.0	120.0	114.0	107.0
218.3L70	126.6	113.0	117.0	121.0	121.0	119.0	116.0	110.0	103.0
218.3L80	125.0	113.0	114.0	118.0	119.0	119.0	116.0	109.0	101.0
218.4L40	132.5	127.0	128.0	127.0	121.0	117.0	113.0	105.0	100.0
218.4L50	133.4	124.0	129.0	128.0	124.0	122.0	118.0	114.0	105.0
218.4L60	135.4	120.0	128.0	131.0	130.0	125.0	122.0	115.0	109.0
218.4L70	128.0	114.0	118.0	122.0	123.0	121.0	117.0	111.0	104.0
218.4L80	125.9	113.0	115.0	119.0	122.0	121.0	118.0	111.0	102.0
218.5L40	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
218.5L50	134.4	126.0	130.0	129.0	125.0	122.0	118.0	115.0	106.0
218.5L60	136.0	121.0	128.0	132.0	130.0	126.0	123.0	115.0	110.0
218.5L70	129.0	114.0	119.0	123.0	124.0	122.0	118.0	113.0	106.0
218.5L80	128.3	115.0	116.0	120.0	123.0	123.0	119.0	114.0	105.0
219.1L40	125.9	118.0	120.0	122.0	117.0	112.0	106.0	99.0	94.0
219.1L50	123.4	114.0	119.0	118.0	115.0	111.0	106.0	102.0	92.0
219.1L60	119.7	109.0	114.0	115.0	112.0	109.0	106.0	98.0	88.0
219.1L70	115.6	104.0	107.0	110.0	110.0	108.0	103.0	97.0	87.0
219.1L80	114.8	104.0	106.0	109.0	109.0	107.0	104.0	96.0	85.0
219.2L40	129.4	121.0	124.0	125.0	121.0	116.0	112.0	105.0	99.0
219.2L50	128.6	117.0	123.0	124.0	121.0	118.0	113.0	109.0	100.0
219.2L60	125.4	113.0	119.0	121.0	118.0	115.0	113.0	105.0	97.0
219.2L70	119.9	107.0	111.0	114.0	114.0	113.0	109.0	102.0	94.0
219.2L80	118.7	107.0	109.0	112.0	113.0	112.0	109.0	102.0	91.0
219.3L40	130.6	123.0	126.0	126.0	120.0	116.0	113.0	106.0	101.0
219.3L50	130.6	119.0	125.0	126.0	123.0	120.0	116.0	113.0	104.0
219.3L60	128.4	115.0	121.0	124.0	122.0	119.0	11[illegible].0	110.0	102.0
219.3L70	123.2	109.0	113.0	117.0	118.0	116.0	113.0	107.0	99.0
219.3L80	122.2	109.0	111.0	115.0	117.0	116.0	113.0	105.0	96.0
219.4L40	132.7	125.0	127.0	127.0	126.0	120.0	116.0	109.0	105.0
219.4L50	133.3	122.0	127.0	128.0	127.0	123.0	119.0	116.0	107.0
219.4L60	132.2	118.0	125.0	127.0	126.0	123.0	121.0	115.0	108.0
219.4L70	126.2	112.0	117.0	120.0	121.0	119.0	115.0	109.0	101.0
219.4L80	125.2	112.0	115.0	118.0	120.0	119.0	115.0	108.0	99.0
219.5L40	133.1	127.0	128.0	128.0	123.0	118.0	113.0	106.0	104.0
219.5L50	134.6	123.0	129.0	130.0	127.0	124.0	119.0	115.0	107.0
219.5L60	132.5	119.0	126.0	128.0	126.0	122.0	119.0	113.0	106.0

NOTE: THESE ARE FREE FIELD VALUES

HM-AP-55-C NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
219.5L70	127.0	114.0	119.0	121.0	121.0	120.0	115.0	110.0	103.0
219.5L80	126.9	114.0	117.0	120.0	122.0	120.0	116.0	110.0	101.0
220.1L40	127.0	118.0	121.0	123.0	119.0	114.0	110.0	103.0	97.0
220.1L50	126.6	115.0	121.0	122.0	119.0	116.0	112.0	109.0	99.0
220.1L60	123.0	111.0	117.0	119.0	115.0	112.0	110.0	102.0	94.0
220.1L70	117.9	105.0	109.0	112.0	112.0	111.0	107.0	101.0	91.0
220.1L80	115.4	104.0	106.0	109.0	110.0	108.0	105.0	97.0	87.0
220.2L40	[illegible]	121.0	124.0	124.0	119.0	115.0	110.0	102.0	97.0
220.2L50	[illegible]	118.0	124.0	124.0	121.0	118.0	113.0	109.0	99.0
220.2L60	[illegible]	113.0	120.0	122.0	120.0	116.0	113.0	105.0	97.0
220.2L70	121.3	108.0	113.0	115.0	116.0	114.0	110.0	104.0	96.0
220.2L80	118.9	107.0	109.0	112.0	113.0	113.0	109.0	102.0	91.0
220.3L40	130.8	124.0	126.0	126.0	120.0	116.0	110.0	103.0	100.0
220.3L50	131.4	121.0	126.0	127.0	123.0	120.0	115.0	112.0	103.0
220.3L60	129.6	115.0	122.0	125.0	124.0	120.0	116.0	109.0	102.0
220.3L70	123.2	110.0	114.0	117.0	118.0	116.0	112.0	106.0	98.0
220.3L80	122.1	110.0	111.0	115.0	117.0	116.0	112.0	105.0	95.0
220.4L40	132.1	126.0	126.0	126.0	121.0	117.0	111.0	104.0	101.0
220.4L50	133.3	123.0	127.0	129.0	126.0	122.0	118.0	114.0	105.0
220.4L60	131.4	117.0	124.0	127.0	125.0	122.0	119.0	111.0	105.0
220.4L70	126.2	112.0	117.0	120.0	121.0	119.0	115.0	109.0	102.0
220.4L80	124.7	111.0	114.0	116.0	119.0	118.0	116.0	109.0	100.0
220.5L40	134.7	128.0	129.0	131.0	122.0	118.0	113.0	105.0	102.0
220.5L50	134.3	124.0	129.0	130.0	126.0	122.0	115.0	114.0	106.0
220.5L60	132.9	119.0	126.0	128.0	127.0	123.0	120.0	113.0	106.0
220.5L70	127.4	113.0	118.0	122.0	122.0	120.0	116.0	111.0	103.0
220.5L80	125.8	113.0	115.0	119.0	120.0	120.0	[illegible]	110.0	101.0
221.1L40	126.8	120.0	121.0	122.0	118.0	113.0	108.0	101.0	95.0
221.1L50	125.6	117.0	121.0	122.0	119.0	115.0	110.0	106.0	97.0
221.1L60	124.5	112.0	118.0	120.0	118.0	114.0	111.0	103.0	95.0
221.1L70	119.1	107.0	111.0	117.0	113.0	112.0	108.0	101.0	92.0
221.1L80	117.2	106.0	107.0	111.0	112.0	110.0	106.0	98.0	87.0
221.2L40	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
221.2L50	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
221.2L60	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
221.2L70	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
221.2L80	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
221.3L40	130.7	125.0	126.0	125.0	120.0	116.0	111.0	104.0	99.0
221.3L50	131.5	122.0	126.0	127.0	123.0	120.0	116.0	111.0	103.0
221.3L60	131.7	117.0	124.0	127.0	126.0	122.0	120.0	113.0	106.0
221.3L70	125.1	111.0	115.0	119.0	120.0	118.0	114.0	109.0	102.0
221.3L80	123.4	110.0	112.0	116.0	118.0	117.0	115.0	108.0	99.0
221.4L40	132.7	127.0	128.0	127.0	122.0	118.0	113.0	106.0	102.0
221.4L50	133.3	124.0	129.0	128.0	124.0	121.0	117.0	113.0	104.0
221.4L60	133.6	119.0	126.0	129.0	128.0	124.0	120.0	113.0	107.0
221.4L70	127.0	113.0	117.0	121.0	122.0	120.0	115.0	109.0	102.0
221.4L80	125.0	112.0	114.0	117.0	120.0	119.0	116.0	109.0	100.0
221.5L40	133.5	128.0	129.0	127.0	123.0	119.0	115.0	109.0	103.0
221.5L50	134.3	125.0	130.0	129.0	125.0	122.0	119.0	115.0	106.0
221.5L60	135.0	120.0	127.0	131.0	129.0	125.0	122.0	116.0	109.0
221.5L70	128.5	114.0	119.0	122.0	123.0	122.0	118.0	113.0	106.0
221.5L80	127.5	113.0	115.0	119.0	123.0	122.0	118.0	111.0	103.0

NOTE: THESE ARE FREE FIELD VALUES

HM-AP-55-C NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
222.1L40	112.6	102.0	100.0	99.0	102.0	109.0	106.0	101.0	92.0
222.1L50	112.5	100.0	99.0	99.0	102.0	109.0	106.0	102.0	91.0
222.1L60	111.3	97.0	97.0	100.0	104.0	107.0	105.0	99.0	89.0
222.1L70	110.5	95.0	95.0	97.0	103.0	106.0	105.0	99.0	91.0
222.1L80	109.8	97.0	95.0	96.0	100.0	106.0	104.0	99.0	89.0
222.2L40	117.0	109.0	106.0	104.0	105.0	112.0	111.0	103.0	97.0
222.2L50	116.7	105.0	104.0	103.0	106.0	112.0	111.0	108.0	97.0
222.2L60	115.2	102.0	102.0	104.0	107.0	111.0	109.0	102.0	94.0
222.2L70	113.8	100.0	100.0	101.0	106.0	110.0	107.0	102.0	94.0
222.2L80	112.7	101.0	99.0	100.0	103.0	108.0	107.0	103.0	94.0
222.3L40	119.2	114.0	112.0	108.0	107.0	112.0	111.0	104.0	96.0
222.3L50	117.8	109.0	108.0	106.0	107.0	113.0	111.0	106.0	94.0
222.3L60	116.3	105.0	106.0	107.0	108.0	111.0	110.0	102.0	93.0
222.3L70	114.8	103.0	103.0	104.0	107.0	110.0	108.0	103.0	94.0
222.3L80	114.5	104.0	102.0	103.0	105.0	109.0	109.0	104.0	95.0
222.4L40	122.1	118.0	117.0	111.0	108.0	112.0	111.0	103.0	96.0
222.4L50	119.1	113.0	112.0	109.0	108.0	112.0	110.0	107.0	95.0
222.4L60	117.4	107.0	108.0	109.0	109.0	111.0	111.0	104.0	95.0
222.4L70	116.2	105.0	105.0	106.0	109.0	111.0	109.0	104.0	96.0
222.4L80	115.7	106.0	105.0	105.0	107.0	110.0	109.0	105.0	96.0
222.5L40	125.3	121.0	121.0	116.0	111.0	113.0	111.0	104.0	97.0
222.5L50	121.9	116.0	116.0	113.0	110.0	113.0	112.0	109.0	98.0
222.5L60	119.3	109.0	111.0	112.0	111.0	112.0	112.0	105.0	96.0
222.5L70	117.8	106.0	107.0	108.0	111.0	112.0	111.0	105.0	98.0
222.5L80	117.3	108.0	107.0	107.0	109.0	111.0	111.0	106.0	97.0
223.1L40	116.0	109.0	104.0	101.0	104.0	112.0	109.0	102.0	93.0
223.1L50	115.6	105.0	103.0	100.0	104.0	112.0	109.0	105.0	95.0
223.1L60	114.2	103.0	102.0	102.0	105.0	110.0	108.0	102.0	93.0
223.1L70	113.0	101.0	100.0	101.0	105.0	109.0	107.0	101.0	92.0
223.1L80	112.9	101.0	99.0	99.0	103.0	109.0	107.0	102.0	93.0
223.2L40	119.1	115.0	112.0	107.0	106.0	112.0	109.0	102.0	93.0
223.2L50	118.1	111.0	109.0	106.0	106.0	113.0	110.0	107.0	96.0
223.2L60	116.8	107.0	106.0	106.0	108.0	112.0	110.0	103.0	94.0
223.2L70	116.4	105.0	104.0	105.0	109.0	112.0	109.0	104.0	96.0
223.2L80	115.6	106.0	103.0	103.0	106.0	111.0	109.0	105.0	96.0
223.3L40	124.2	120.0	119.0	113.0	110.0	115.0	112.0	105.0	96.0
223.3L50	120.5	115.0	113.0	110.0	109.0	114.0	111.0	107.0	97.0
223.3L60	118.8	110.0	110.0	110.0	110.0	113.0	111.0	104.0	94.0
223.3L70	117.0	106.0	107.0	107.0	110.0	112.0	109.0	103.0	95.0
223.3L80	116.8	108.0	106.0	106.0	108.0	111.0	110.0	106.0	97.0
223.4L40	127.3	123.0	123.0	118.0	113.0	115.0	113.0	104.0	96.0
223.4L50	123.4	118.0	118.0	114.0	112.0	115.0	112.0	107.0	96.0
223.4L60	120.3	111.0	113.0	113.0	112.0	113.0	112.0	104.0	95.0
223.4L70	118.6	108.0	109.0	110.0	112.0	113.0	110.0	104.0	96.0
223.4L80	118.7	110.0	109.0	108.0	110.0	113.0	112.0	105.0	98.0
223.5L40	129.7	125.0	126.0	121.0	116.0	116.0	113.0	105.0	97.0
223.5L50	126.3	121.0	122.0	118.0	114.0	115.0	112 0	108.0	98.0
223.5L60	123.0	115.0	116.0	116.0	115.0	115.0	113.0	106.0	98.0
223.5L70	120.4	111.0	111.0	112.0	114.0	114.0	111.0	106.0	98.0
223.5L80	119.6	111.0	110.0	110.0	111.0	114.0	112.0	107.0	99.0
224.3L40	116.0	106.0	103.0	101.0	105.0	112.0	110.0	104.0	98.0
224.3L50	115.5	104.0	102.0	101.0	105.0	112.0	109.0	105.0	95.0

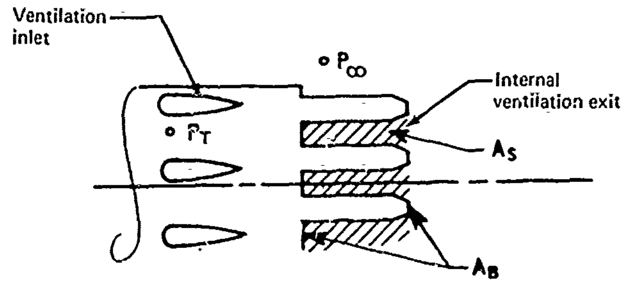
NOTE: THESE ARE FREE FIELD VALUES

HM-AP-55-C NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
224.3L60	114.8	101.0	101.0	102.0	106.0	111.0	109.0	102.0	93.0
224.3L70	114.2	99.0	99.0	101.0	106.0	110.0	108.0	104.0	96.0
224.3L80	112.9	100.0	98.0	99.0	103.0	109.0	107.0	103.0	94.0
224.4L40	118.7	113.0	110.0	105.0	106.0	113.0	111.0	105.0	97.0
224.4L50	117.7	109.0	107.0	104.0	106.0	113.0	111.0	108.0	98.0
224.4L60	115.8	104.0	105.0	106.0	108.0	112.0	111.0	105.0	96.0
224.4L70	115.4	102.0	102.0	103.0	107.0	111.0	109.0	105.0	97.0
224.4L80	115.6	104.0	102.0	102.0	105.0	111.0	110.0	105.0	98.0
224.5L40	122.0	117.0	116.0	111.0	109.0	114.0	112.0	106.0	102.0
224.5L50	119.1	112.0	111.0	108.0	108.0	113.0	111.0	109.0	98.0
224.5L60	118.3	107.0	108.0	109.0	109.0	113.0	112.0	106.0	98.0
224.5L70	117.5	105.0	106.0	106.0	110.0	113.0	110.0	106.0	99.0
224.5L80	117.4	106.0	105.0	105.0	108.0	112.0	112.0	108.0	99.0
224.6L40	125.5	121.0	121.0	11[illegible].0	111.0	115.0	113.0	106.0	104.0
224.6L50	122.4	116.0	116.0	113.0	111.0	115.0	113.0	109.0	98.0
224.6L60	120.1	110.0	112.0	112.0	112.0	114.0	112.0	104.0	95.0
224.6L70	117.[illegible]	107.0	108.0	109.0	111.0	111.0	109.0	103.0	94.0
224.6L80	116.6	108.0	107.0	107.0	108.0	111.0	109.0	104.0	95.0
224.7L40	127.9	123.0	124.0	119.0	114.0	115.0	114.0	106.0	102.0
224.7L50	124.0	118.0	118.0	115.0	113.0	116.0	114.0	110.0	101.0
224.7L60	122.1	112.0	113.0	114.0	114.0	116.0	115.0	107.0	99.0
224.7L70	119.8	108.0	110.0	111.0	113.0	114.0	112.0	107.0	99.0
224.7L80	119.6	110.0	109.0	109.0	111.0	114.0	113.0	108.0	99.0
225.1L40	116.8	109.0	105.0	101.0	105.0	113.0	110.0	104.0	96.0
225.1L50	115.6	106.0	103.0	102.0	105.0	113.0	110.0	107.0	96.0
225.1L60	115.1	103.0	102.0	103.0	106.0	111.0	109.0	103.0	94.0
225.1L70	114.2	102.0	100.0	102.0	107.0	110.0	107.0	103.0	94.0
225.1L80	114.1	102.1	100.0	100.0	105.0	110.0	108.0	104.0	95.0
225.2L40	119.1	114.0	111.0	106.0	106.0	113.0	111.0	104.0	96.0
225.2L50	118.6	111.0	108.0	105.0	106.0	114.0	111.0	109.0	98.0
225.2L60	117.7	106.0	106.0	106.0	108.0	113.0	112.0	106.0	97.0
225.2L70	116.6	104.0	103.0	105.0	109.0	112.0	110.0	106.0	98.0
225.2L80	117.0	105.0	103.0	103.0	107.0	112.0	112.0	107.0	99.0
225.3L40	123.5	119.0	118.0	112.0	110.0	115.0	113.0	106.0	99.0
225.3L40	121.5	115.0	114.0	111.0	110.0	115.0	113.0	110.0	100.0
225.3L60	120.2	109.0	110.0	111.0	111.0	115.0	114.0	107.0	100.0
225.3L70	118.0	107.0	107.0	108.0	111.0	113.0	110.0	106.0	97.0
225.3L80	118.2	108.0	106.0	106.0	110.0	113.0	112.0	107.0	98.0
225.4L40	126.5	122.0	122.0	117.0	113.0	115.0	113.0	107.0	102.0
225.4L50	123.9	118.0	118.0	114.0	112.0	116.0	114.0	111.0	102.0
225.4L60	121.8	111.0	113.0	113.0	113.0	116.0	115.0	109.0	101.0
225.4L70	120.0	108.0	109.0	110.0	113.0	115.0	112.0	108.0	100.0
225.4L80	119.7	110.0	109.0	109.0	111.0	114.0	113.0	109.0	100.0
225.5L40	128.9	124.0	125.0	120.0	115.0	116.0	114.0	107.0	103.0
225.5L50	125.9	120.0	121.0	117.0	115.0	116.0	114.0	111.0	101.0
225.5L60	123.9	114.0	116.0	116.0	116.0	117.0	115.0	109.0	102.0
225.5L70	121.9	111.0	112.0	113.0	115.0	116.0	114.0	109.0	102.0
225.5L80	120.2	111.0	110.0	111.0	112.0	114.0	113.0	109.0	101.0

NOTE: THESE ARE FREE FIELD VALUES

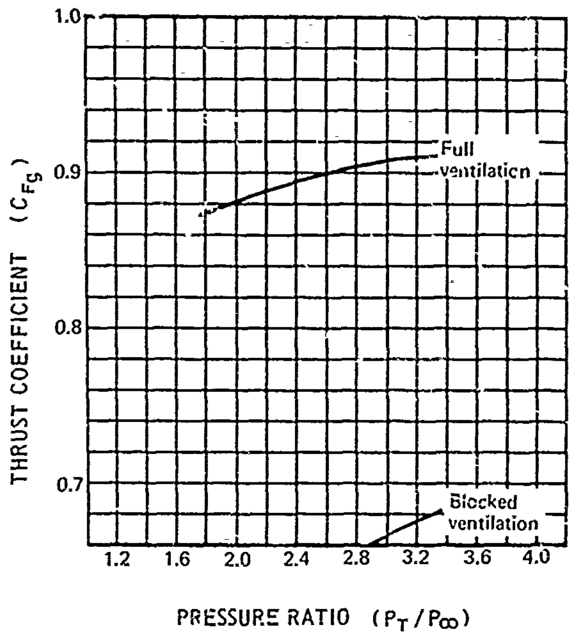
HM-AP-56

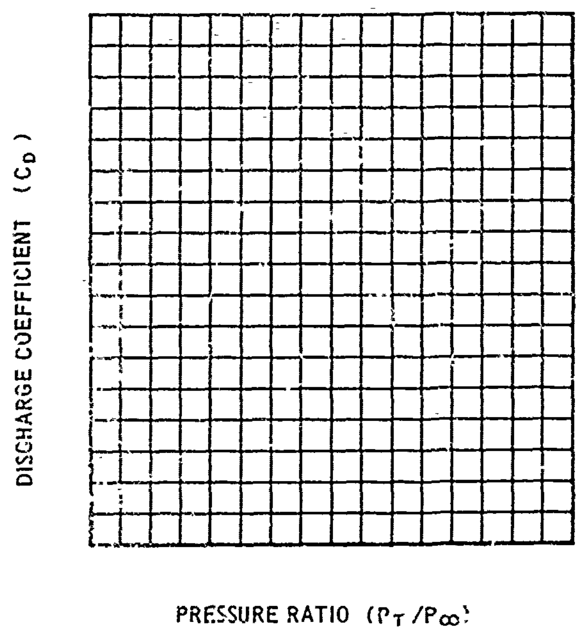


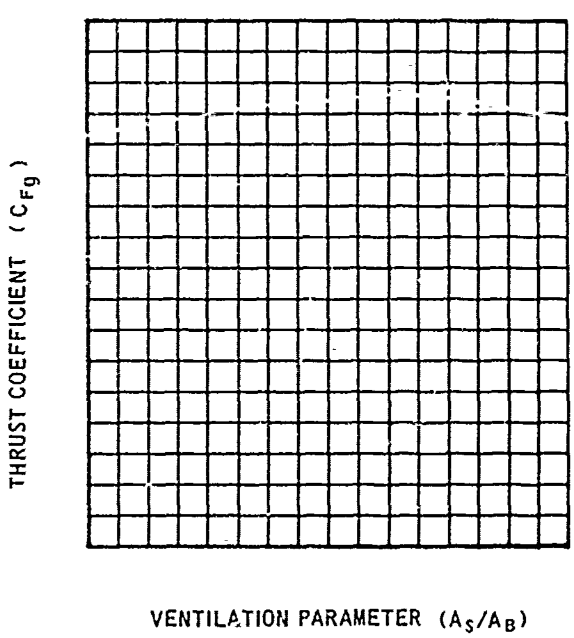
37 TUBE, AREA RATIO 4.0 NOZZLE
INTERNALLY VENTILATED
NO-EJECTOR

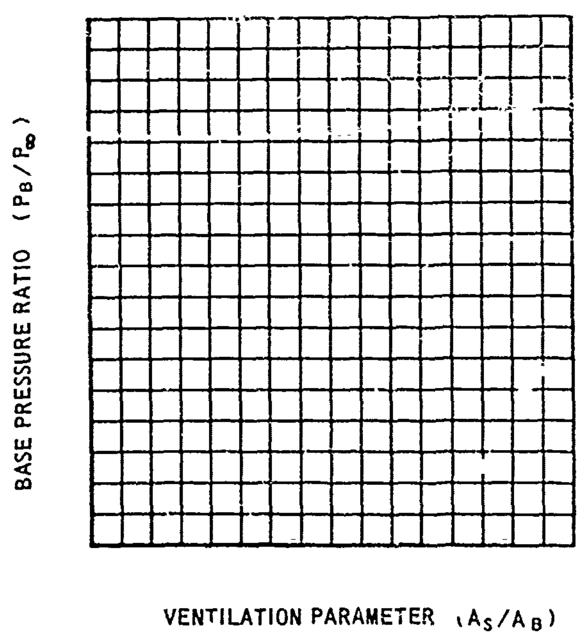
$$C_{F_g} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$









HM-AP-57 NOZZLE

12 SPOKES, AR 1.86

NO PICTURE AVAILABLE

Description:

Number of Elements: 12 Spokes

Area Ratio: 1.86

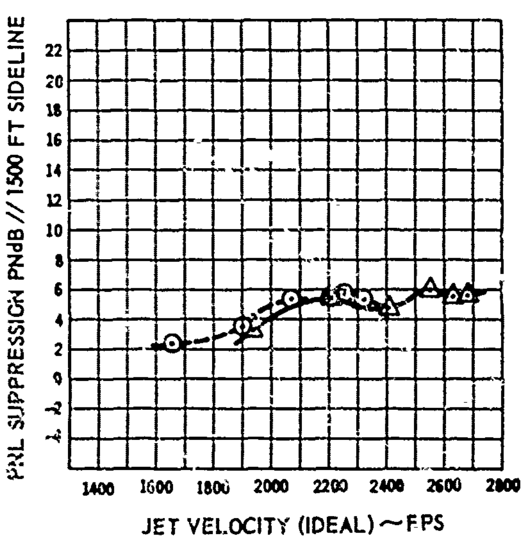
Spoke Penetration: 75%

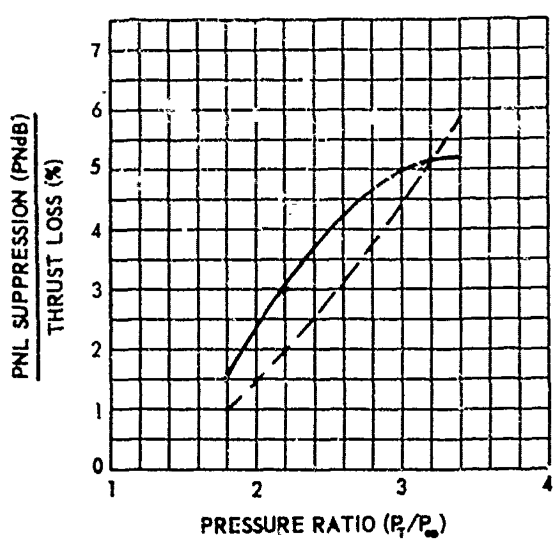
Flow Area: 13.2 Square Inches

Exit Cant Angle: 0 Degrees

Ventilation Gutter Cant Angle: 77°

Material: 321 CRES

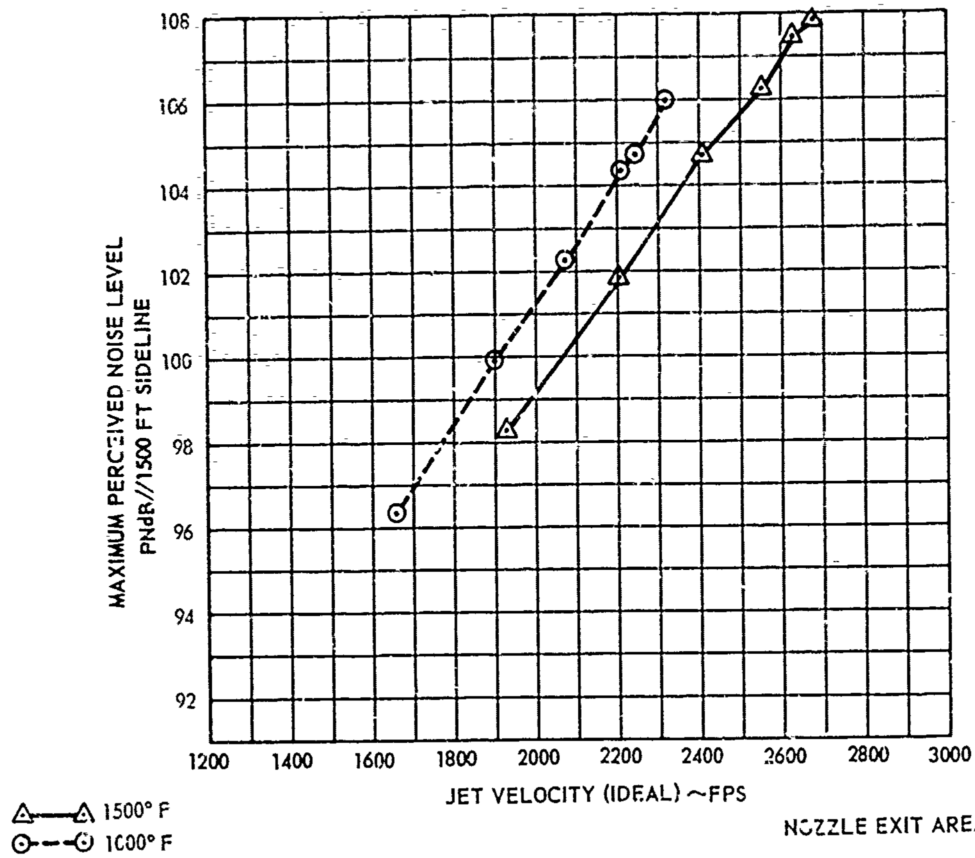




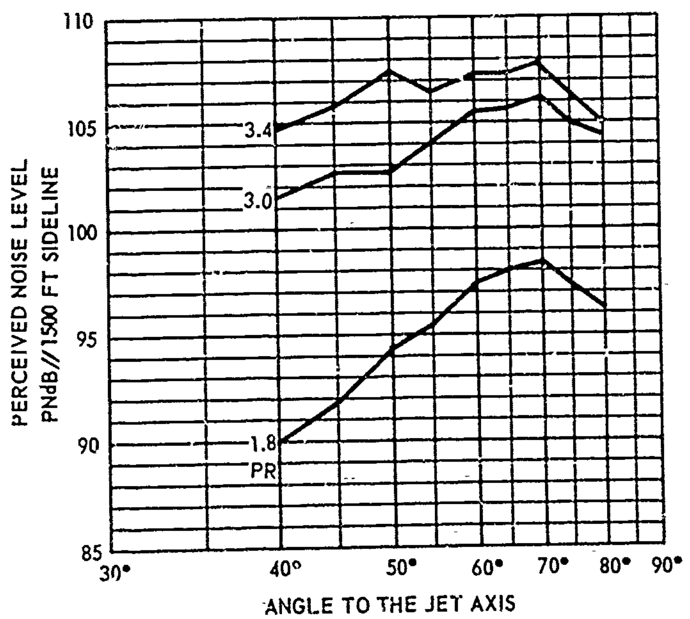
NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-57 NOZZLE
(12 SPOKES)
AR 1.86
SCALE FACTOR: 8:1

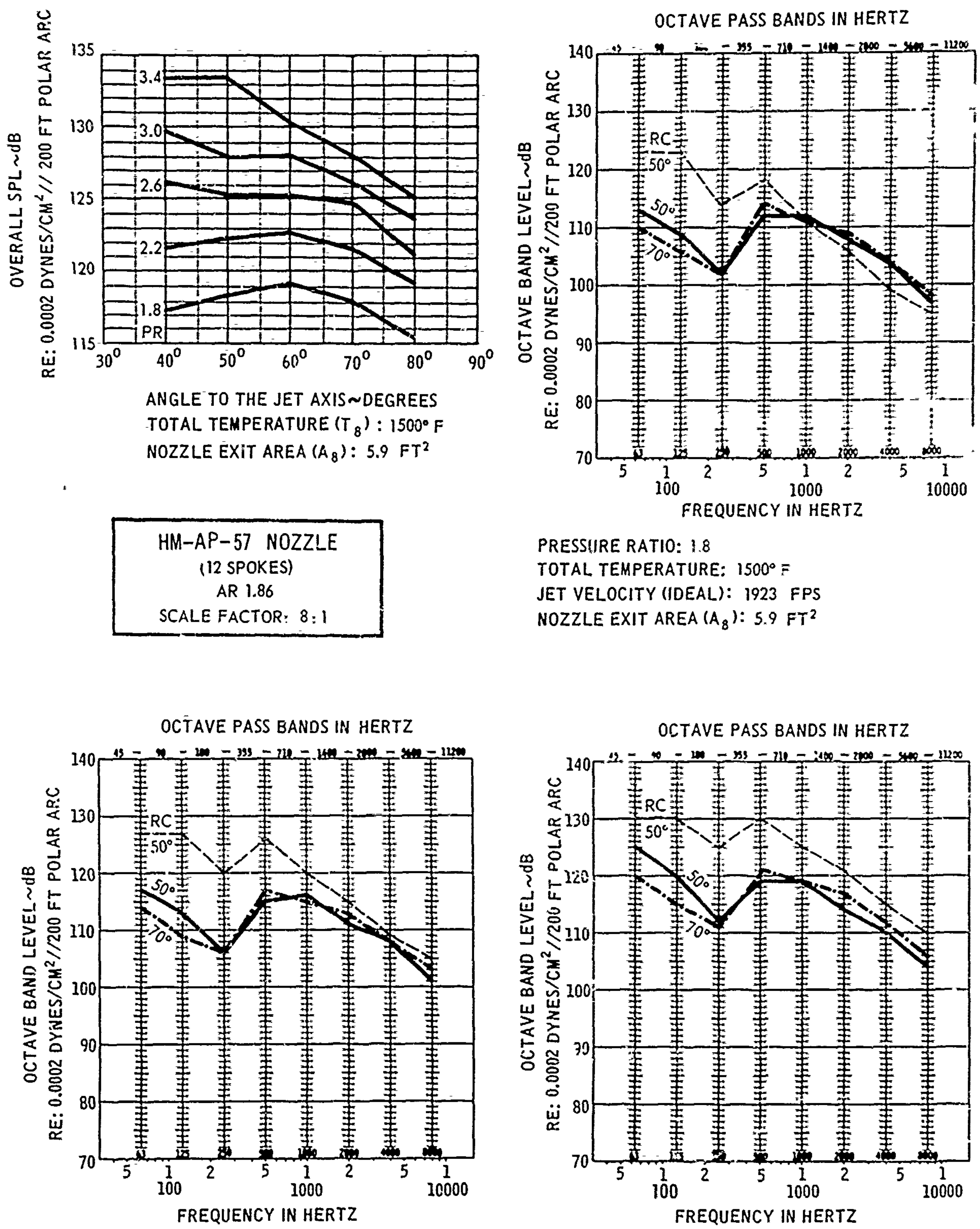


NOZZLE EXIT AREA (A_8): 5.9 FT^2



TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE



HM-AP-57 NOZZLE
(12 SPOKES)
AR 1.86
SCALE FACTOR: 8:1

PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-57 NOZZLE

Remarks

The data acquired in the HM-AP-57 Nozzle tests included ground reflection interference. The spectra was arbitrarily corrected for ground reflection interference and it was noted that perceived noise level suppression values improved by 1 to 2.5 PNdB. For instance at pressure ratio 3.0 and total temperature of 1500°F the free field suppression value was 8.0 while the ground reflection influenced value was 6.0. See Reference D27.

HM-AP-57 NOZZLE

Test Facility: Annex D (Cell #1)
Nozzle and microphone height is 20 Inches

Date: January 10, 1968

T_{amb}: 38°F

R.H.: 73%

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
2037	1.8	1000°F	1659 fps	HM-AP-57
2049	1.8	"	1659	"
2038	2.2	"	1900	"
2050	2.2	"	1900	"
2039	2.6	"	2073	"
2051	2.6	"	2073	"
2040	3.0	"	2205	"
2052	3.0	"	2205	"
2041	3.2	"	2250	"
2053	3.2	"	2250	"
2042	3.4	"	2311	"
2054	3.4	"	2311	"
2043	1.8	1500°F	1923	"
2055	1.8	"	1923	"
2044	2.2	"	2202	"
2056	2.2	"	2202	"
2045	2.6	"	2402	"
2057	2.6	"	2402	"
2046	3.0	"	2555	"
2058	3.0	"	2555	"
2047	3.2	"	2620	"
2059	3.2	"	2620	"
2048	3.4	"	2678	"
2060	3.4	"	2678	"
2079	1.8	1000°F	1659 fps	4.1 Inch Round Convergent Nozzle
2067	1.8	"	1659	"
2080	2.2	"	1900	"
2068	2.2	"	1900	"
2081	2.6	"	2073	"
2069	2.6	"	2073	"
2082	3.0	"	2205	"
2070	3.0	"	2205	"

HM-AP-57 NOZZLE

2083	3.2	1000°F	2250	4.1 Inch Round Convergent Nozzle
2071	3.2	"	2250	"
2084	3.4	"	2311	"
2072	3.4	"	2311	"
2085	1.8	1500°F	1923	"
2073	1.8	"	1923	"
2086	2.2	"	2202	"
2074	2.2	"	2202	"
2087	2.6	"	2402	"
2075	2.6	"	2402	"
2088	3.0	"	2555	"
2076	3.0	"	2555	"
2089	3.2	"	2620	"
2077	3.2	"	2620	"
2090	3.4	"	2678	"
2078	3.4	"	2678	"

HM-AP-57 NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM²//25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
2037 L40	116.3	110.0	106.0	100.0	109.0	111.0	107.0	103.0	95.0
2037 L50	117.2	111.0	108.0	103.0	111.0	111.0	108.0	103.0	95.0
2037 L60	118.6	110.0	108.0	106.0	114.0	112.0	109.0	104.0	97.0
2037 L70	117.7	108.0	105.0	104.0	114.0	111.0	108.0	104.0	97.0
2037 L80	114.8	105.0	103.0	100.0	110.0	109.0	106.0	102.0	94.0
2049 L45	116.1	112.0	107.0	100.0	109.0	108.0	105.0	102.0	93.0
2049 L55	116.7	111.0	108.0	102.0	111.0	109.0	105.0	103.0	95.0
2049 L[illegible]	117.2	111.0	107.0	102.0	112.0	110.0	107.0	103.0	96.0
2049 L65	116.9	110.0	106.0	101.0	112.0	110.0	107.0	103.0	96.0
2049 L75	113.5	106.0	102.0	98.0	108.0	107.0	105.0	101.0	94.0
2038 L40	119.3	114.0	109.0	102.0	111.0	113.0	111.0	107.0	99.0
2038 L50	120.2	115.0	111.0	104.0	113.0	114.0	109.0	107.0	100.0
2038 L60	120.9	114.0	111.0	105.0	115.0	115.0	111.0	107.0	101.0
2038 L70	119.6	111.0	108.0	104.0	115.0	113.0	111.0	107.0	101.0
2038 L80	116.8	108.0	104.0	102.0	111.0	111.0	109.0	105.0	98.0
2050 L45	119.4	114.0	111.0	104.0	112.0	112.0	110.0	107.0	99.0
2050 L55	120.3	114.0	111.0	105.0	114.0	114.0	110.0	107.0	100.0
2050 L60	120.9	114.0	109.0	106.0	115.0	115.0	112.0	107.0	101.0
2050 L65	120.3	112.0	109.0	105.0	115.0	115.0	111.0	105.0	100.0
2050 L75	117.3	109.0	106.0	102.0	112.0	111.0	109.0	105.0	98.0
2039 L40	123.3	120.0	114.0	107.0	114.0	115.0	113.0	109.0	100.0
2039 L50	123.1	118.0	114.0	108.0	115.0	117.0	112.0	109.0	103.0
2039 L60	123.7	117.0	114.0	109.0	117.0	118.0	114.0	110.0	104.0
2039 L70	121.8	114.0	110.0	105.0	117.0	115.0	113.0	109.0	104.0
2039 L80	118.9	110.0	107.0	104.0	113.0	113.0	111.0	108.0	101.0
2051 L45	122.9	119.0	114.0	107.0	115.0	115.0	112.0	109.0	-0.
2051 L55	122.7	117.0	114.0	108.0	116.0	116.0	112.0	109.0	103.0
2051 L60	123.4	117.0	114.0	108.0	117.0	117.0	114.0	109.0	104.0
2051 L65	123.0	115.0	112.0	108.0	118.0	117.0	113.0	109.0	104.0
2051 L75	119.3	111.0	108.0	105.0	114.0	113.0	111.0	107.0	101.0
2040 L40	126.5	124.0	118.0	110.0	117.0	116.0	114.0	110.0	101.0
2040 L50	126.0	122.0	117.0	110.0	118.0	119.0	114.0	110.0	104.0
2040 L60	125.9	120.0	116.0	111.0	119.0	120.0	116.0	111.0	105.0
2040 L70	123.8	116.0	113.0	109.0	119.0	117.0	115.0	110.0	105.0
2040 L80	120.6	112.0	109.0	106.0	115.0	114.0	113.0	109.0	102.0
2052 L45	126.1	123.0	117.0	110.0	118.0	117.0	[illegible]	110.0	-0.
2052 L55	125.6	121.0	117.0	109.0	119.0	116.0	119.0	111.0	104.0
052 L60	123.7	117.0	114.0	109.0	118.0	117.0	114.0	109.0	104.0
52 L65	124.9	118.0	115.0	110.0	120.0	118.0	119.0	110.0	105.0
2052 L75	121.6	114.0	111.0	107.0	116.0	115.0	113.0	110.0	103.0
2041 L40	128.4	126.0	121.0	112.0	118.0	117.0	114.0	110.0	101.0
2041 L50	126.8	123.0	118.0	111.0	119.0	119.0	115.0	111.0	105.0
2041 L60	126.5	121.0	117.0	111.0	120.0	120.0	116.0	112.0	105.0
2041 L70	124.7	117.0	114.0	109.0	120.0	118.0	115.0	111.0	106.0
2041 L80	124.5	121.0	111.0	107.0	117.0	116.0	115.0	111.0	104.0
2053 L45	126.8	124.0	118.0	111.0	118.0	117.0	119.0	111.0	-0.
2053 L55	126.6	124.0	117.0	109.0	118.0	117.0	113.0	110.0	103.0
2053 L60	125.3	119.0	116.0	111.0	119.0	119.0	115.0	111.0	105.0
2053 L65	125.6	121.0	115.0	109.0	120.0	118.0	114.0	109.0	105.0
2053 L75	122.5	115.0	111.0	108.0	117.0	116.0	119.0	110.0	104.0
2042 L40	130.5	128.0	124.0	114.0	120.0	118.0	114.0	111.0	104.0
2042 L50	128.2	125.0	120.0	113.0	120.0	119.0	115.0	111.0	105.0
2042 L60	127.6	123.0	118.0	113.0	121.0	120.0	117.0	112.0	106.0
2042 L70	125.9	119.0	115.0	111.0	121.0	119.0	116.0	112.0	106.0
2062 L80	123.0	115.0	112.0	108.0	117.0	117.0	115.0	111.0	104.0
2054 L45	128.7	126.0	121.0	113.0	120.0	117.0	115.0	111.0	-0.
2054 L55	127.2	124.0	118.0	111.0	120.0	118.0	114.0	111.0	104.0
2054 L60	126.3	121.0	117.0	111.0	120.0	119.0	116.0	111.0	106.0
2054 L65	126.3	120.0	117.0	112.0	121.0	119.0	116.0	111.0	106.0
2054 L75	123.4	116.0	113.0	109.0	118.0	116.0	115.0	111.0	104.0
2043 L40	117.3	112.0	107.0	100.0	110.0	111.0	108.0	104.0	95.0
2043 L50	118.5	113.0	109.0	102.0	112.0	112.0	108.0	104.0	97.0
2043 L60	119.2	113.0	108.0	104.0	113.0	113.0	110.0	105.0	98.0
2043 L70	118.1	110.0	106.0	102.0	114.0	111.0	109.0	104.0	98.0
2043 L80	115.2	107.0	103.0	100.0	110.0	109.0	107.0	103.0	95.0
2055 L45	117.7	114.0	107.0	101.0	110.0	110.0	107.0	104.0	95.0
2055 L55	118.4	113.0	109.0	103.0	112.0	112.0	107.0	104.0	97.0
2055 L60	119.0	113.0	108.0	104.0	113.0	113.0	109.0	104.0	98.0
2055 L65	118.8	112.0	107.0	104.0	114.0	112.0	109.0	104.0	98.0
2055 L75	116.5	109.0	104.0	101.0	112.0	110.0	107.0	103.0	96.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-57 NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
2044 L40	121.7	118.0	112.0	105.0	113.0	114.0	111.0	108.0	99.0
2044 L50	122.2	117.0	113.0	106.0	115.0	114.0	111.0	108.0	101.0
2044 L60	122.8	117.0	112.0	107.0	116.0	117.0	113.0	108.0	102.0
2044 L70	121.7	114.0	109.0	106.0	117.0	115.0	113.0	109.0	103.0
2044 L80	119.1	113.0	106.0	103.0	113.0	113.0	110.0	106.0	99.0
2056 L45	121.4	117.0	112.0	105.0	114.0	114.0	111.0	108.0	-0.
2055 L55	122.0	117.0	113.0	106.0	115.0	115.0	111.0	108.0	101.0
2056 L60	122.6	117.0	113.0	108.0	116.0	116.0	113.0	108.0	102.0
2056 L65	122.6	116.0	112.0	107.0	118.0	116.0	112.0	107.0	102.0
2056 L75	119.5	112.0	107.0	103.0	115.0	113.0	110.0	106.0	99.0
2045 L40	126.2	124.0	117.0	109.0	116.0	116.0	112.0	109.0	100.0
2045 L50	125.2	121.0	117.0	110.0	117.0	116.0	113.0	110.0	103.0
2045 L60	125.2	120.0	115.0	111.0	118.0	119.0	115.0	111.0	105.0
2045 L70	124.7	118.0	113.0	109.0	120.0	115.0	115.0	110.0	104.0
2045 L80	121.1	115.0	109.0	106.0	115.0	115.0	112.0	108.0	100.0
2057 L45	125.1	122.0	117.0	109.0	116.0	116.0	113.0	110.0	-0.
2057 L55	125.1	121.0	116.0	110.0	117.0	118.0	113.0	110.0	104.0
2057 L60	125.6	121.0	116.0	111.0	118.0	119.0	115.0	110.0	105.0
2057 L65	125.2	119.0	114.0	111.0	120.0	119.0	114.0	109.0	104.0
2057 L75	122.5	116.0	111.0	107.0	117.0	116.0	113.0	109.0	103.0
2046 L40	129.3	128.0	122.0	112.0	118.0	116.0	113.0	110.0	101.0
2046 L50	128.0	125.0	120.0	112.0	119.0	119.0	114.0	110.0	104.0
2046 L60	128.1	124.0	118.0	112.0	121.0	121.0	117.0	112.0	106.0
2046 L70	126.2	120.0	115.0	111.0	121.0	119.0	117.0	112.0	106.0
2046 L80	123.6	117.0	112.0	109.0	118.0	117.0	114.0	111.0	103.0
2058 L45	129.1	127.0	121.0	112.0	119.0	117.0	114.0	111.0	-0.
2058 L55	128.1	125.0	118.0	112.0	120.0	120.0	115.0	112.0	105.0
2058 L60	128.0	124.0	110.0	113.0	121.0	120.0	117.0	112.0	106.0
2058 L65	126.9	122.0	117.0	112.0	121.0	119.0	116.0	111.0	106.0
2058 L75	124.5	118.0	113.0	109.0	120.0	117.0	114.0	110.0	104.0
2047 L40	132.1	130.0	126.0	115.0	120.0	117.0	114.0	111.0	104.0
2047 L50	130.4	128.0	122.0	115.0	121.0	120.0	114.0	111.0	106.0
2047 L60	128.7	125.0	119.0	113.0	121.0	121.0	117.0	112.0	107.0
2047 L70	127.4	121.0	116.0	112.0	123.0	120.0	117.0	112.0	107.0
2047 L80	123.5	117.0	113.0	109.0	118.0	117.0	115.0	111.0	104.0
2059 L45	131.1	129.0	124.0	115.0	120.0	118.0	115.0	112.0	105.0
2059 L55	128.9	126.0	120.0	113.0	121.0	119.0	115.0	112.0	105.0
2059 L60	128.5	125.0	119.0	113.0	121.0	120.0	117.0	112.0	107.0
2059 L65	127.8	123.0	118.0	113.0	122.0	120.0	117.0	111.0	106.0
2059 L75	125.1	119.0	114.0	111.0	120.0	118.0	115.0	111.0	104.0
2048 L40	133.4	131.0	128.0	117.0	121.0	118.0	115.0	111.0	105.0
2048 L50	133.5	132.0	125.0	116.0	122.0	120.0	114.0	111.0	106.0
2048 L60	130.2	127.0	120.0	114.0	123.0	121.0	118.0	113.0	108.0
2048 L70	128.1	123.0	118.0	113.0	123.0	120.0	117.0	112.0	107.0
2048 L80	125.0	121.0	113.0	109.0	118.0	117.0	115.0	111.0	103.0
2060 L45	132.5	130.0	127.0	117.0	121.0	118.0	115.0	112.0	106.0
2060 L55	130.6	128.0	122.0	115.0	122.0	120.0	115.0	113.0	107.0
2060 L60	130.0	127.0	120.0	114.0	122.0	121.0	118.0	113.0	108.0
2060 L65	128.8	125.0	119.0	114.0	122.0	120.0	117.0	112.0	107.0
2060 L75	126.0	120.0	115.0	111.0	121.0	119.0	115.0	112.0	105.0
2079 L40	126.2	122.0	123.0	114.0	115.0	107.0	101.0	95.0	95.0
2079 L50	124.3	121.0	120.0	110.0	114.0	106.0	104.0	95.0	93.0
2079 L60	120.0	116.0	113.0	107.0	114.0	109.0	104.0	98.0	91.0
2079 L70	116.7	111.0	109.0	105.0	112.0	107.0	103.0	97.0	91.0
2079 L80	113.8	107.0	106.0	104.0	109.0	105.0	101.0	95.0	88.0
2067 L45	125.2	122.0	121.0	111.0	114.0	107.0	100.0	94.0	-0.
2067 L55	122.4	119.0	117.0	109.0	114.0	109.0	103.0	98.0	-0.
2067 L60	120.3	116.0	114.0	107.0	114.0	109.0	104.0	97.0	91.0
2067 L65	118.2	113.0	111.0	106.0	113.0	108.0	104.0	97.0	91.0
2067 L75	115.1	109.0	107.0	105.0	110.0	106.0	103.0	96.0	89.0
2080 L40	130.2	125.0	126.0	120.0	123.0	115.0	109.0	104.0	100.0
2080 L50	128.5	124.0	124.0	116.0	121.0	115.0	110.0	104.0	99.0
2080 L60	124.5	119.0	118.0	113.0	119.0	114.0	110.0	104.0	98.0
2080 L70	120.8	114.0	113.0	110.0	116.0	112.0	108.0	103.0	97.0
2080 L80	117.2	109.0	108.0	107.0	113.0	109.0	106.0	101.0	93.0
2068 L45	129.5	125.0	125.0	118.0	122.0	115.0	109.0	103.0	100.0
2068 L55	126.6	122.0	121.0	115.0	120.0	114.0	109.0	104.0	98.0
2068 L60	124.4	119.0	118.0	112.0	119.0	114.0	110.0	104.0	98.0
2068 L65	122.1	116.0	115.0	110.0	117.0	113.0	109.0	103.0	98.0
2068 L75	118.9	112.0	110.0	108.0	114.0	111.0	108.0	102.0	94.0
2081 L40	133.1	127.0	129.0	123.0	126.0	120.0	115.0	109.0	106.0
2081 L50	131.5	126.0	127.0	120.0	125.0	119.0	115.0	110.0	104.0
2081 L60	127.6	122.0	121.0	116.0	122.0	118.0	114.0	109.0	103.0
2081 L70	124.4	117.0	115.0	113.0	120.0	116.0	114.0	108.0	103.0
2081 L80	121.2	112.0	111.0	111.0	116.0	115.0	111.0	107.0	99.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

HM-AP-57 NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
2069 L45	133.2	128.0	128.0	122.0	127.0	120.0	116.0	111.0	107.0
2069 L55	129.4	124.0	124.0	118.0	123.0	118.0	114.0	109.0	104.0
2069 L60	127.7	122.0	121.0	116.0	122.0	118.0	115.0	109.0	104.0
2069 L65	125.5	118.0	117.0	113.0	121.0	118.0	114.0	109.0	103.0
2069 L75	122.7	114.0	113.0	111.0	118.0	116.0	113.0	107.0	100.0
2082 L40	134.6	129.0	130.0	126.0	127.0	121.0	117.0	111.0	108.0
2082 L50	134.1	128.0	129.0	123.0	126.0	123.0	118.0	113.0	108.0
2082 L60	130.[illegible]	124.0	123.0	120.0	124.0	121.0	117.0	112.0	107.0
2082 L70	127.2	119.0	118.0	117.0	122.0	120.0	117.0	111.0	107.0
2082 L80	124.5	114.0	113.0	116.0	120.0	116.0	114.0	110.0	103.0
2070 L45	134.8	129.0	130.0	125.0	128.0	123.0	118.0	113.0	109.0
2070 L55	132.2	125.0	127.0	122.0	126.0	121.0	118.0	113.0	108.0
2070 L60	130.2	124.0	123.0	119.0	125.0	121.0	117.0	112.0	107.0
2070 L65	127.9	120.0	119.0	118.0	123.0	120.0	117.0	111.0	107.0
2070 L75	125.7	116.0	115.0	116.0	121.0	119.0	116.0	111.0	104.0
2083 L40	137.0	130.0	132.0	132.0	128.0	122.0	117.0	112.0	109.0
2083 L50	135.0	129.0	130.0	126.0	128.0	124.0	119.0	115.0	110.0
2083 L60	131.2	124.0	124.0	123.0	126.0	121.0	118.0	113.0	107.0
2083 L70	128.2	120.0	119.0	119.0	123.0	121.0	117.0	112.0	107.0
2083 L80	126.5	115.0	115.0	120.0	122.0	117.0	115.0	111.0	105.0
2071 L45	136.0	130.0	131.0	128.0	129.0	123.0	119.0	114.0	110.0
2071 L55	133.3	127.0	128.0	125.0	127.0	122.0	118.0	113.0	109.0
2071 L60	131.4	125.0	124.0	124.0	125.0	122.0	118.0	113.0	108.0
2071 L65	129.0	121.0	121.0	120.0	124.0	121.0	117.0	112.0	107.0
2071 L75	126.7	117.0	116.0	118.0	122.0	120.0	116.0	111.0	105.0
2084 L40	137.3	130.0	133.0	132.0	127.0	122.0	118.0	112.0	109.0
2084 L50	135.5	129.0	131.0	126.0	129.0	124.0	120.0	115.0	110.0
2084 L60	131.8	125.0	125.0	123.0	126.0	122.0	119.0	114.0	108.0
2084 L70	128.5	120.0	119.0	119.0	124.0	121.0	117.0	113.0	108.0
2084 L80	126.6	116.0	116.0	119.0	122.0	119.0	116.0	111.0	105.0
2072 L45	136.3	130.0	132.0	127.0	129.0	123.0	120.0	115.0	110.0
2072 L55	133.9	128.0	128.0	124.0	128.0	123.0	119.0	114.0	109.0
2072 L60	132.0	125.0	125.0	124.0	126.0	123.0	119.0	114.0	109.0
2072 L65	129.5	122.0	121.0	120.0	124.0	122.0	118.0	113.0	108.0
2072 L75	127.4	118.0	117.0	117.0	122.0	121.0	117.0	113.0	106.0
2085 L40	128.9	124.0	125.0	118.0	121.0	111.0	105.0	99.0	97.0
2085 L50	127.0	123.0	123.0	114.0	118.0	111.0	106.0	99.0	95.0
2085 L60	124.2	120.0	118.0	111.0	118.0	112.0	107.0	100.0	94.0
2085 L70	119.9	115.0	112.0	106.0	115.0	109.0	106.0	99.0	93.0
2085 L80	116.7	110.0	108.0	107.0	112.0	106.0	104.0	98.0	90.0
2073 L45	128.0	124.0	124.0	117.0	118.0	111.0	105.0	99.0	97.0
2073 L55	125.7	122.0	121.0	113.0	117.0	111.0	106.0	98.0	94.0
2073 L60	123.5	119.0	118.0	111.0	117.0	112.0	106.0	100.0	94.0
2073 L65	121.1	116.0	114.0	109.0	116.0	111.0	106.0	99.0	94.0
2073 L75	117.9	112.0	110.0	107.0	113.0	108.0	105.0	98.0	91.0
2086 L40	132.8	127.0	128.0	122.0	127.0	119.0	114.0	108.0	105.0
2086 L50	132.2	127.0	127.0	120.0	126.0	120.0	115.0	109.0	105.0
2086 L60	128.3	123.0	122.0	116.0	123.0	117.0	113.0	108.0	101.0
2086 L70	123.9	118.0	116.0	112.0	119.0	115.0	111.0	105.0	99.0
2086 L80	119.7	112.0	111.0	109.0	115.0	112.0	108.0	103.0	96.0
2074 L45	132.4	127.0	127.0	121.0	127.0	119.0	114.0	108.0	104.0
2074 L55	129.9	125.0	125.0	118.0	123.0	118.0	113.0	108.0	102.0
2074 L60	128.0	123.0	122.0	116.0	122.0	117.0	113.0	107.0	101.0
2074 L65	125.3	120.0	118.0	113.0	120.0	116.0	111.0	106.0	100.0
2074 L75	121.8	115.0	113.0	111.0	117.0	114.0	110.0	105.0	97.0
2087 L40	133.3	128.0	129.0	123.0	126.0	119.0	115.0	110.0	107.0
2087 L50	134.0	128.0	129.0	123.0	128.0	122.0	118.0	112.0	108.0
2087 L60	130.6	125.0	124.0	119.0	125.0	121.0	116.0	112.0	100.0
2087 L70	126.3	120.0	118.0	115.0	121.0	118.0	115.0	110.0	104.0
2087 L80	122.9	114.0	113.0	113.0	118.0	116.0	113.0	106.0	101.0
2075 L45	134.6	129.0	130.0	124.0	128.0	121.0	117.0	112.0	108.0
2075 L55	132.7	127.0	127.0	122.0	127.0	121.0	117.0	112.0	107.0
2075 L60	130.3	124.0	124.0	119.0	125.0	121.0	116.0	111.0	106.0
2075 L65	127.4	121.0	120.0	116.0	122.0	117.0	115.0	110.0	105.0
2075 L75	124.9	117.0	115.0	113.0	120.0	118.0	115.0	109.0	102.0
2088 L40	134.6	130.0	130.0	124.0	127.0	120.0	116.0	111.0	107.0
2088 L50	135.8	130.0	130.0	125.0	130.0	125.0	121.0	115.0	110.0
2088 L60	133.0	127.0	126.0	122.0	128.0	123.0	119.0	115.0	109.0
2088 L70	128.4	122.0	120.0	118.0	123.0	120.0	117.0	112.0	107.0
2088 L80	125.6	116.0	115.0	115.0	121.0	119.0	116.0	111.0	104.0
2076 L45	135.6	130.0	131.0	125.0	129.0	123.0	118.0	113.0	110.0
2076 L55	135.1	129.0	129.0	124.0	130.0	124.0	120.0	115.0	111.0
2076 L60	133.0	127.0	126.0	122.0	128.0	123.0	119.0	114.0	109.0
2076 L65	129.9	123.0	122.0	119.0	125.0	121.0	118.0	113.0	108.0
2076 L75	127.1	119.0	117.0	117.0	122.0	120.0	117.0	112.0	105.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

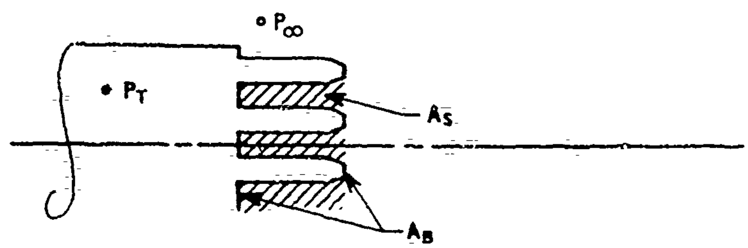
HM-AP-57 NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
2089 L40	135.9	131.0	132.0	125.0	127.0	121.0	117.0	112.0	108.0
2089 L50	136.8	131.0	131.0	126.0	131.0	120.0	122.0	116.0	112.0
2089 L60	134.0	128.0	127.0	123.0	129.0	124.0	120.0	116.0	110.0
2089 L70	129.7	122.0	121.0	119.0	125.0	122.0	118.0	113.0	108.0
2089 L80	126.3	117.0	116.0	116.0	122.0	119.0	116.0	112.0	105.0
2077 L45	136.4	131.0	132.0	126.0	129.0	123.0	119.0	114.0	110.0
2077 L55	135.9	129.0	130.0	125.0	131.0	125.0	122.0	117.0	112.0
2077 L60	134.0	128.0	127.0	123.0	129.0	124.0	120.0	116.0	110.0
2077 L65	131.4	125.0	124.0	120.0	126.0	123.0	119.0	115.0	109.0
2077 L75	128.3	120.0	118.0	117.0	124.0	121.0	116.0	113.0	107.0
2090 L40	137.0	131.0	133.0	130.0	127.0	122.0	118.0	113.0	109.0
2090 L50	137.5	131.0	133.0	128.0	131.0	125.0	122.0	117.0	112.0
2090 L60	134.3	128.0	127.0	124.0	129.0	125.0	121.0	117.0	111.0
2090 L70	130.3	123.0	121.0	120.0	125.0	123.0	120.0	114.0	109.0
2090 L80	128.2	118.0	117.0	119.0	123.0	122.0	119.0	114.0	107.0
2078 L45	137.3	131.0	133.0	130.0	129.0	124.0	119.0	115.0	111.0
2078 L55	136.7	130.0	131.0	127.0	131.0	124.0	122.0	117.0	112.0
2078 L60	134.4	128.0	128.0	124.0	129.0	125.0	121.0	116.0	111.0
2078 L65	131.8	125.0	124.0	121.0	127.0	123.0	119.0	114.0	110.0
2078 L75	129.0	121.0	119.0	118.0	124.0	122.0	119.0	114.0	107.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

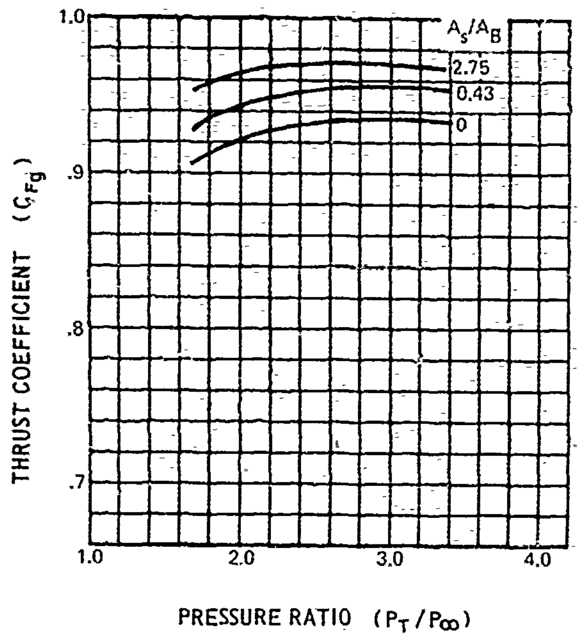
216

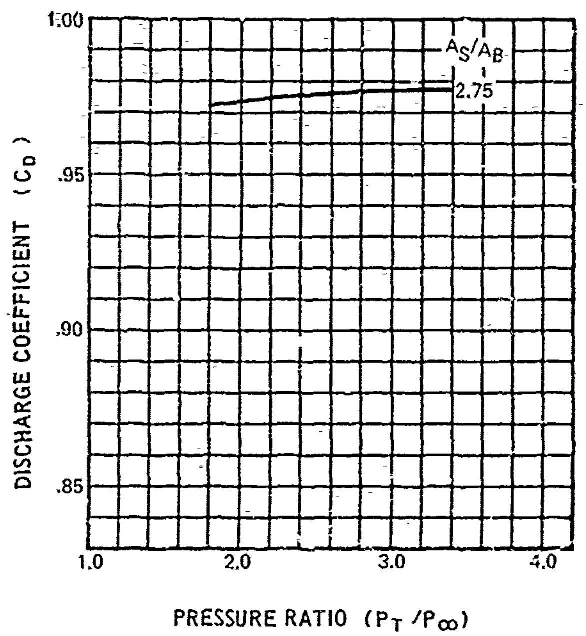
HM-AP-57

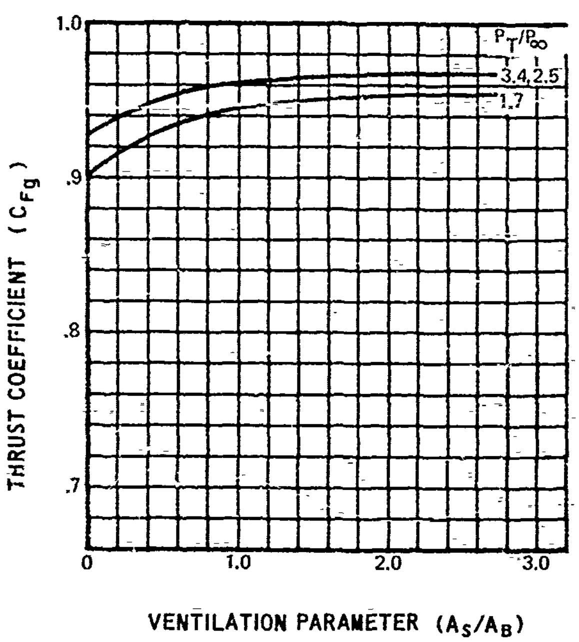


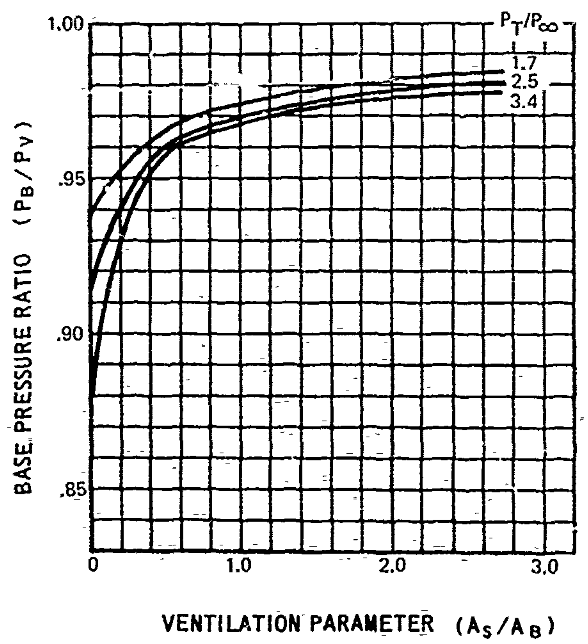
$$C_{Fg} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$









HM-AP-58-A NOZZLE

(42 TUBES, 6 CLUSTERS OF 7 TUBES EACH, AR 9.7)

Description:

The HM-AP-58-A nozzle is a 42-tube array. There are 6 clusters of tubes with 7 tubes in each cluster. The center of each cluster is located at a 5.75 inch radius from the array center. The tube clusters are equally spaced at 60 degree are intervals. Each tube has a 12-spoke nozzle termination.

Number of Elements: 42 tubes with 12-spoke nozzle type ends

Area Ratio: 9.7

Tube Spacing (center-to-center): [illegible] inches between tubes in each cluster

Flow Area: 1[illegible] square inches

Exit Cant Angle: 0 degrees

Length of Tubes: 7 inches

Tube Terminations: 12 spokes with A_R = 1.66

75% spoke penetration

0.92 inches outside diameter

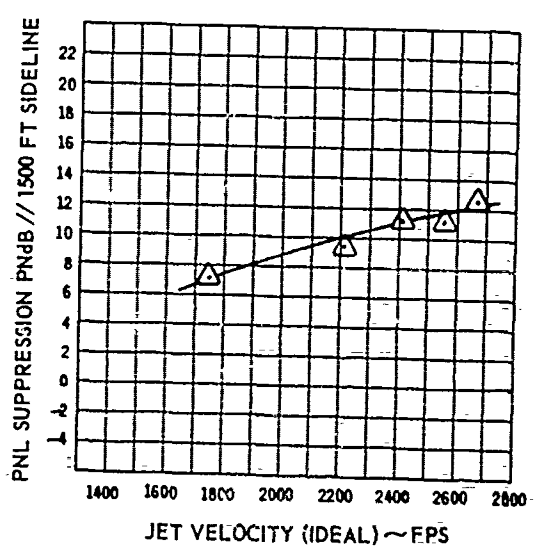
A_P = 0.357 square inches

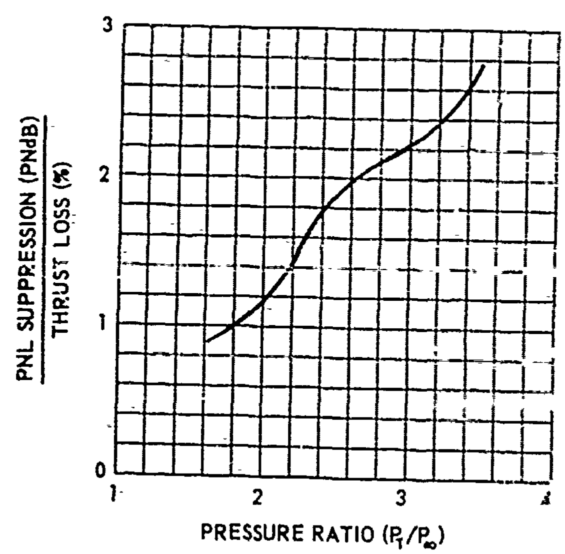
0 degrees cant angle

[illegible] degrees ventilation gutter cant angle

Material: 321 CRES

NO PICTURE AVAILABLE



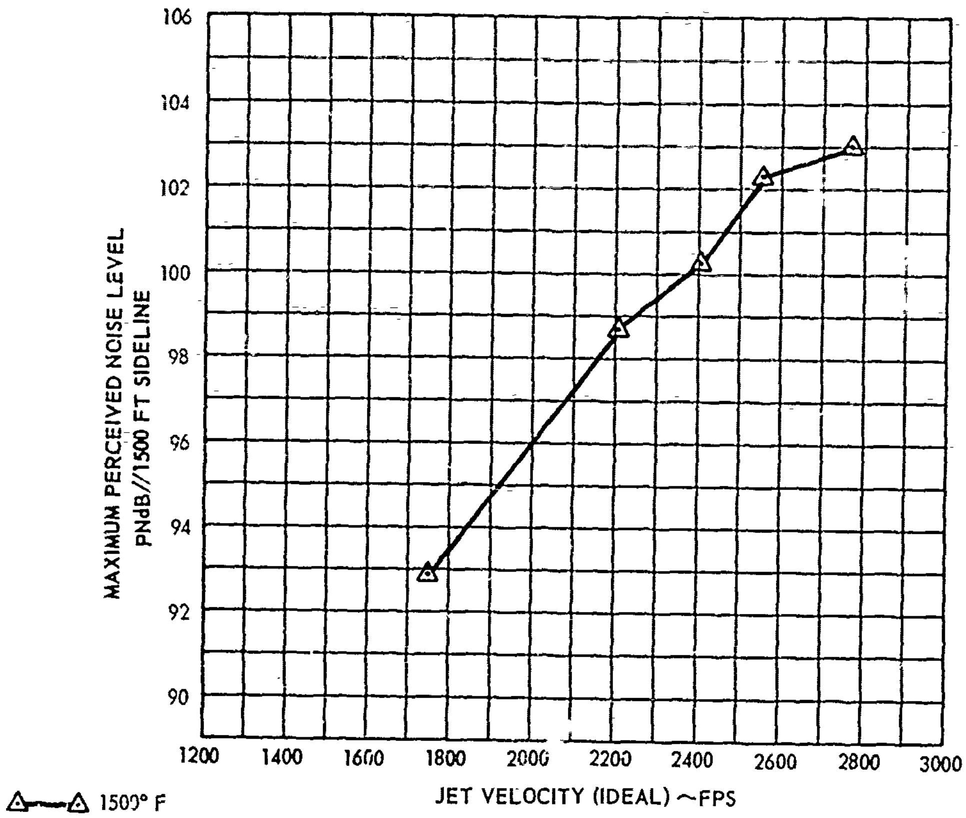


△—△ 1500° F

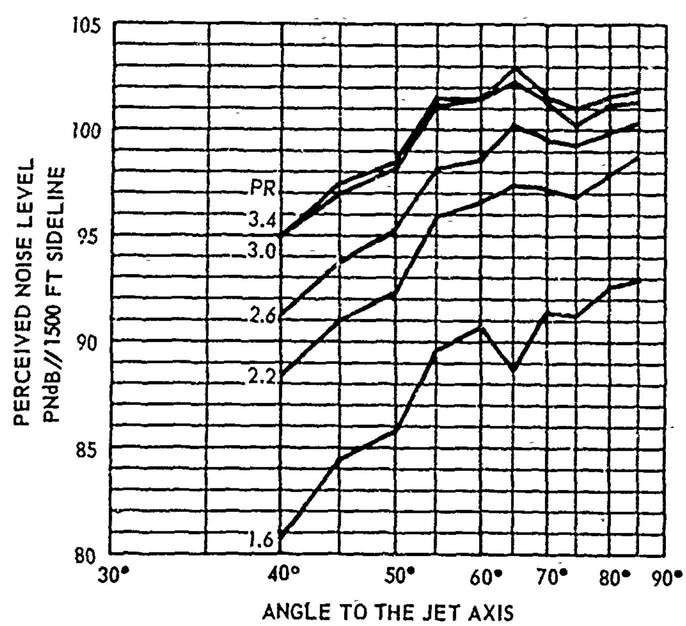
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

HM-AP-58-A NOZZLE
(42 TUBES, 6 CLUSTERS OF 7 TUBES EACH)
AR 9.7
SCALE FACTOR: 8:1

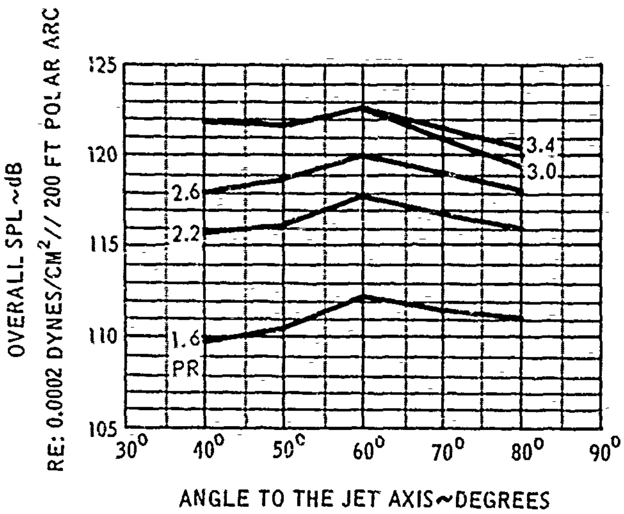


NOZZLE EXIT AREA (A_8): 12.6 FT^2

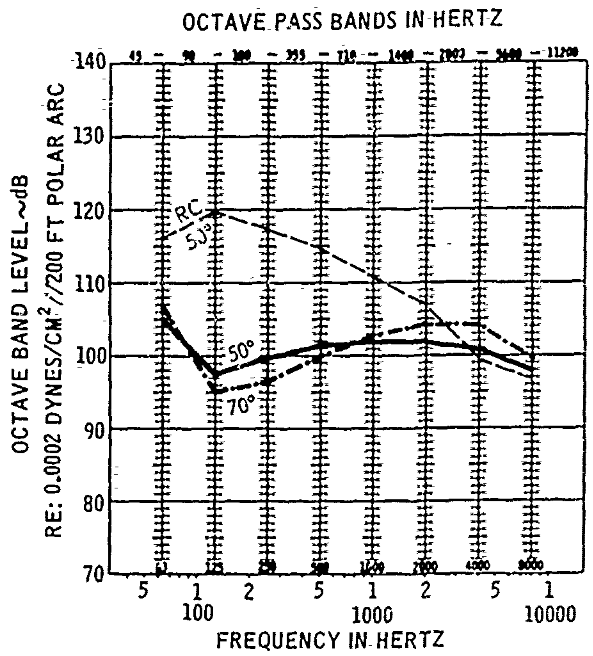


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT^2

FREE FIELD VALUES

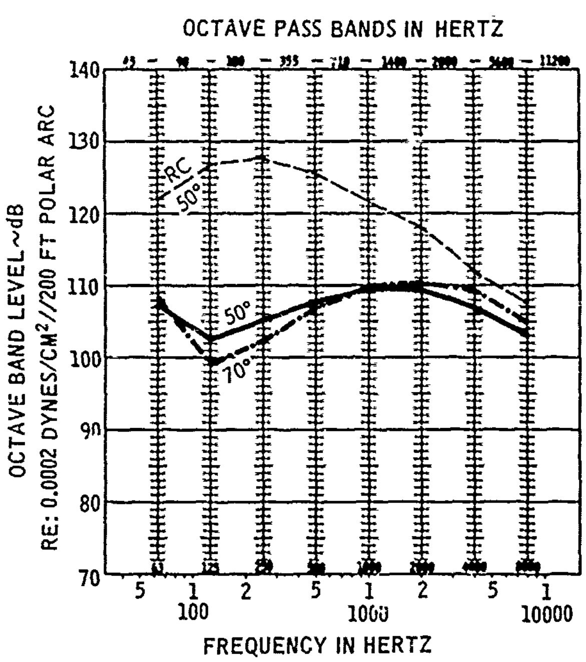


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT^2

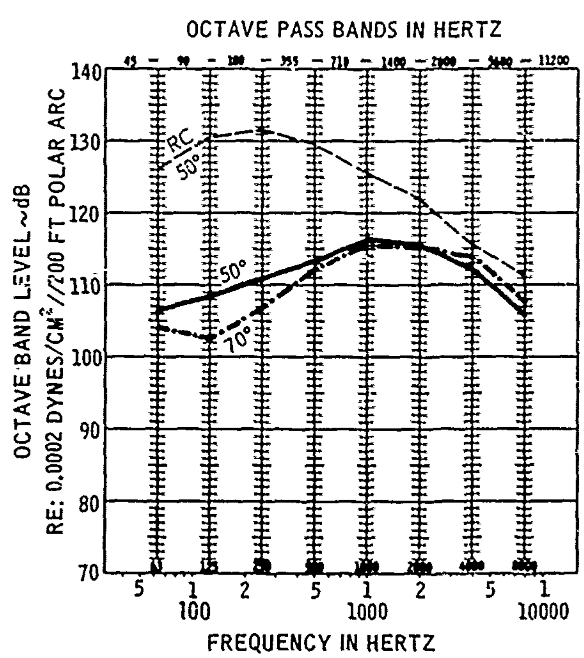


PRESSURE RATIO: 1.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1750 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT^2

HM-AP-58-A NOZZLE
(42 TUBES, 6 CLUSTERS OF 7 TUBES EACH)
AR 9.7
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT^2



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT^2

FREE FIELD VALUES

HM-AP-58-A NOZZLE

(42 Tubes, 6 Clusters of 7 Tubes Each)

Remarks

The HM-AP-58-A Nozzle indicated that 6 clusters of 7 tubes each will provide about 2 PNdB more suppression at pressure ratios > 3.0 as compared to a 2-row annulus configuration of 42 tubes (HM-AP-59-A). See Reference D28.

HM-AP-58-A NOZZLE

Test Facility: HNTF

Date: ca June 1969

T_{amb}: data not available

R.H.: data not available

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
10.1	1.6	1500°F	1750 fps	HM-AP-58-A
10.2	2.2	"	2202	"
10.3	2.6	"	2402	"
10.4	3.0	"	2555	"
10.5	3.4	"	2678	"
14.1	1.6	1500°F	1750 fps	4.1 Inch Round Convergent Nozzle
14.2	2.2	"	2202	"
14.3	2.6	"	2402	"
14.4	3.0	"	2555	"
14.5	3.4	"	2678	"

HM-AP-58-A NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
10-1 L40	109.7	106.7	96.7	96.8	98.6	98.8	98.4	99.8	97.9
10-1 L45	110.3	104.5	98.6	99.4	100.6	101.3	101.7	102.0	98.0
10-1 L50	110.4	104.9	97.5	99.6	101.3	101.9	102.1	101.1	97.9
10-1 L55	112.7	107.8	97.1	100.4	102.8	104.3	104.0	104.3	100.9
10-1 L60	112.3	105.8	100.7	99.0	102.1	104.1	104.8	104.5	101.2
10-1 L65	110.3	106.6	95.6	96.6	99.2	103.7	101.3	101.3	98.2
10-1 L70	111.6	103.4	94.9	96.3	100.0	103.0	104.3	104.2	99.6
10-1 [illegible]5	110.5	102.9	94.3	96.5	100.2	102.7	104.4	103.4	98.4
10-1 L80	111.1	103.9	94.0	94.7	98.5	102.0	104.1	105.5	101.5
10-1 L85	111.3	104.8	93.6	94.9	98.2	102.0	104.0	105.6	101.9
10-2 L40	115.8	108.7	102.0	102.8	106.2	108.8	107.6	108.1	104.8
10-2 L45	116.3	106.7	103.2	104.1	107.7	110.1	109.3	108.5	103.2
10-2 L50	116.1	107.3	102.6	104.9	107.8	109.6	109.3	107.2	102.7
10-2 L55	118.3	109.1	102.2	106.3	109.9	111.8	111.0	110.6	106.5
10-2 L60	117.9	108.3	103.9	104.9	109.4	111.5	111.0	110.0	106.5
10-2 L65	117.6	105.1	[illegible]	104.0	109.1	111.0	111.4	110.7	105.9
10-2 L70	116.9	106.2	99.1	102.2	107.2	110.3	110.6	109.7	104.7
10-2 L75	116.1	104.5	98.6	102.0	106.6	109.6	110.6	109.0	103.1
10-2 L80	116.1	105.9	97.9	100.0	104.7	108.1	109.7	110.8	106.1
10-2 L85	116.7	106.4	97.4	100.3	104.8	108.6	110.5	111.6	107.1
10-3 L40	118.0	106.5	104.8	105.4	108.7	112.0	110.6	110.2	105.9
10-3 L45	118.9	107.2	106.1	107.0	110.3	113.3	112.1	110.7	104.2
10-3 L50	118.8	107.1	105.7	108.0	110.8	113.3	112.2	109.4	104.2
10-3 L55	120.5	109.0	105.1	109.3	112.6	114.8	113.3	112.3	107.7
10-3 L60	120.0	107.1	105.2	107.8	112.3	114.5	113.2	111.5	107.4
10-3 L65	120.5	105.2	102.9	107.2	112.6	114.4	114.3	113.3	108.1
10-3 L70	119.1	107.3	101.3	105.5	110.3	113.1	113.0	112.0	106.6
10-3 L75	118.4	103.7	100.8	104.6	109.8	112.5	112.8	111.1	105.1
10-3 L80	118.2	104.7	99.7	102.6	107.6	111.5	112.3	112.6	107.5
10-3 L85	118.1	105.5	[illegible]	102.4	107.0	110.9	112.1	112.8	107.9
10-4 L40	121.9	107.8	107.7	109.1	112.4	116.4	115.6	114.3	109.6
10-4 L45	122.1	107.6	108.9	109.9	[illegible]	116.7	115.2	114.0	106.9
10-4 L50	121.7	106.1	108.5	110.7	113.4	116.6	115.7	112.3	106.6
10-4 L55	123.6	106.1	107.8	112.1	115.6	118.5	117.0	115.4	110.3
10-4 L60	122.7	104.9	106.8	110.1	114.8	117.8	116.2	114.2	109.8
10-4 L65	122.8	103.1	104.7	109.2	114.8	117.3	116.9	115.3	109.7
10-4 L70	121.0	104.1	102.7	108.8	112.3	115.6	115.3	113.8	107.9
10-4 L75	119.7	101.4	102.1	106.1	111.2	114.3	114.5	111.7	105.3
10-4 L80	119.4	102.7	100.9	104.1	109.3	113.0	113.7	113.6	108.1
10-4 L85	119.4	100.3	100.4	104.2	109.0	112.7	113.8	113.8	108.6
10-5 L40	121.8	107.7	109.4	110.2	113.0	116.4	115.8	113.6	98.6
10-5 L45	122.5	106.8	110.7	111.4	113.6	117.1	116.5	113.1	105.6
10-5 L50	121.9	106.4	110.2	111.7	113.7	116.8	115.7	111.1	104.7
10-5 L55	123.7	106.2	109.6	113.4	115.9	118.8	116.8	114.3	108.7
10-5 L60	122.7	104.8	108.5	111.6	115.3	118.1	116.0	112.7	107.4
10-5 L65	123.7	103.5	106.7	111.2	116.4	118.8	117.4	115.0	109.0
10-5 L70	121.6	103.2	104.3	108.5	113.6	116.9	115.6	113.2	106.9
10-5 L75	120.6	100.5	103.6	108.1	112.9	115.8	114.9	111.7	104.7
10-5 L80	120.4	100.8	102.5	105.9	111.1	114.8	114.8	113.7	107.7
10-5 L85	120.2	100.6	101.6	105.9	110.6	114.3	114.8	113.6	107.7

NOTE: THESE ARE FREE FIELD VALUES

HM-AP-58-A NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
14-1 L40	125.0	118.6	120.5	118.8	115.6	111.6	105.6	100.8	98.9
14-1 L45	126.3	121.2	122.1	119.0	115.3	111.5	107.0	100.4	100.5
14-1 L50	123.8	116.0	119.7	117.7	114.7	111.2	107.1	99.5	96.8
14-1 L55	123.3	114.2	117.9	117.9	115.5	112.8	109.3	102.5	97.6
14-1 L60	121.0	110.4	114.6	115.0	114.3	112.3	108.6	101.7	96.2
14-1 L65	120.8	110.0	112.8	114.5	115.1	113.0	108.7	103.2	95.6
14-1 L70	118.3	108.3	110.0	111.6	112.3	111.1	107.3	102.3	93.8
14-1 L75	117.0	105.4	108.2	110.5	111.2	109.9	106.4	99.3	91.9
14-1 L80	115.9	106.4	106.4	108.4	110.1	109.1	105.5	100.2	93.0
14-1 L85	116.7	107.1	107.4	109.4	110.5	110.1	106.5	101.7	94.6
14-2 L40	132.9	125.1	126.8	127.5	125.7	121.9	116.9	113.6	109.8
14-2 L45	134.5	127.8	129.2	128.2	126.4	122.8	119.1	114.2	110.7
14-2 L50	132.5	122.1	126.8	127.4	125.4	121.6	118.2	112.0	107.4
14-2 L55	132.1	119.9	125.4	127.3	125.2	122.4	119.6	114.0	109.0
14-2 L60	129.4	115.9	121.9	123.9	123.0	121.3	118.2	112.5	107.6
14-2 L65	128.1	114.5	118.8	121.9	122.7	120.9	117.0	112.8	106.0
14-2 L70	125.8	112.7	115.6	118.7	120.2	119.5	116.4	111.6	102.7
14-2 L75	124.4	110.0	114.0	117.5	118.8	118.1	115.2	108.8	101.1
14-2 L80	123.1	110.8	112.1	115.2	117.2	117.0	114.2	110.1	102.9
14-2 L85	123.7	111.3	112.4	115.8	117.7	118.0	115.0	110.7	103.4
14-3 L40	135.1	127.3	129.1	129.7	127.4	124.0	119.3	116.2	112.3
14-3 L45	136.9	130.2	131.6	130.6	128.4	125.0	121.2	116.4	113.1
14-3 L50	135.5	124.6	129.3	130.3	129.0	125.3	122.0	116.0	111.4
14-3 L55	135.1	121.7	127.5	130.2	128.7	126.1	123.6	118.3	113.6
14-3 L60	132.5	118.3	124.5	126.9	126.4	124.6	121.8	116.5	112.0
14-3 L65	130.7	116.2	121.1	124.1	125.4	123.8	120.5	116.8	110.3
14-3 L70	129.2	114.7	118.3	121.6	123.4	123.2	120.6	116.5	108.3
14-3 L75	127.4	111.8	116.1	119.8	121.8	121.7	118.8	112.7	105.2
14-3 L80	125.2	112.4	114.4	117.5	120.1	120.9	117.8	113.8	106.8
14-3 L85	126.9	113.0	114.3	117.7	121.0	121.7	118.7	114.9	108.2
14-4 L40	135.6	128.9	130.1	130.1	126.9	123.3	118.0	114.3	111.3
14-4 L45	137.6	131.4	132.7	131.4	128.5	124.8	120.7	115.4	113.1
14-4 L50	136.4	126.0	130.5	131.4	129.6	125.7	121.8	115.5	111.3
14-4 L55	136.4	123.3	129.0	131.6	130.1	127.2	124.0	118.2	113.5
14-4 L60	133.4	119.4	125.9	128.1	127.4	125.0	121.3	115.2	110.3
14-4 L65	132.3	118.9	123.1	126.1	127.2	125.0	120.9	116.2	109.4
14-4 L70	129.8	116.2	119.4	122.5	124.2	123.7	120.2	115.2	106.5
14-4 L75	128.7	113.3	117.2	121.1	123.5	123.0	119.4	112.9	105.3
14-4 L80	128.0	113.7	115.5	119.1	122.5	122.9	119.3	115.0	107.9
14-5 L40	138.1	131.5	132.6	132.2	129.3	126.1	121.6	118.8	115.6
14-5 L45	140.1	134.1	135.2	133.6	130.7	127.5	124.1	119.8	116.6
14-5 L50	138.7	128.2	132.9	133.7	[illegible]	128.1	124.7	118.9	114.5
14-5 L55	139.2	125.5	131.6	134.2	133.0	130.2	127.7	122.7	118.6
14-5 L60	135.6	120.9	127.7	130.0	129.6	127.5	124.6	119.3	114.9
14-5 L65	134.5	120.3	124.5	127.7	129.1	127.8	124.4	120.8	114.7
14-5 L70	132.3	117.7	120.7	124.4	126.5	126.6	123.5	119.4	111.1
14-5 L75	131.3	114.9	118.7	123.1	126.0	126.0	122.8	117.3	110.6
14-5 L80	130.6	115.3	117.3	121.1	125.0	125.5	122.4	118.9	112.6
14-5 L85	131.7	115.7	116.6	121.6	126.5	126.4	123.5	120.1	114.5

NOTE: THESE ARE FREE FIELD VALUES

HM-AP-59-A NOZZLE

(42 TUBES, 12 LOBE SPOKE ENDS, ANNULAR ARRAY, AR 8.3)

NO PICTURE AVAILABLE

Description:

The HM-AP-59-A nozzle is a 42-tube annulus array with 21 tubes in the outer row and 21 tubes in the inner row. The tube terminations are individual 12-spoke nozzles.

Number of Elements: 42 tubes with 12-spoke nozzle type ends

Area Ratio: 8.3

Tube Spacing (between inner and outer rows): 1.35 inches

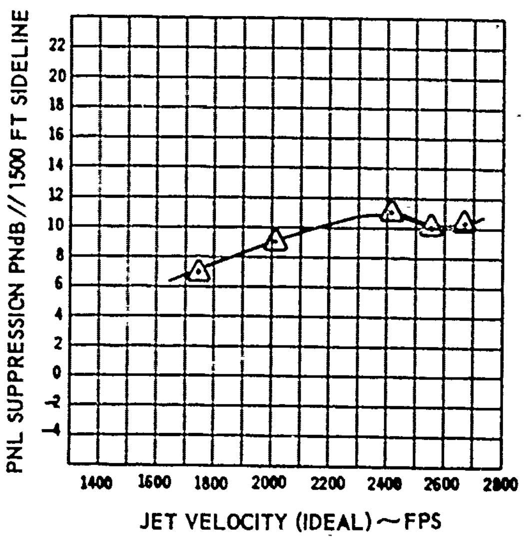
Flow Area: 1[illegible] square inches

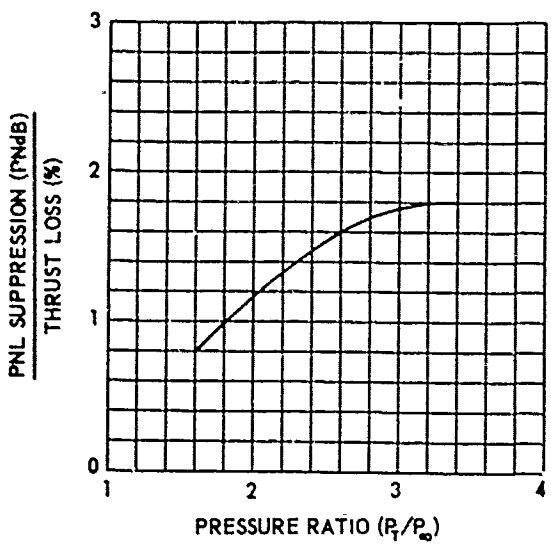
Exit Cant Angle: 0 degrees

Length of Tubes: 7 inches

Tube Terminations:
- 12 spokes with AR = 1.86
- 75% spoke penetration
- 0.92 inches outside diameter
- A_F = 0.357 square inches
- 0 degrees exit cant angle
- 77 degrees ventilation gutter cant angle

Material: 321 CRES



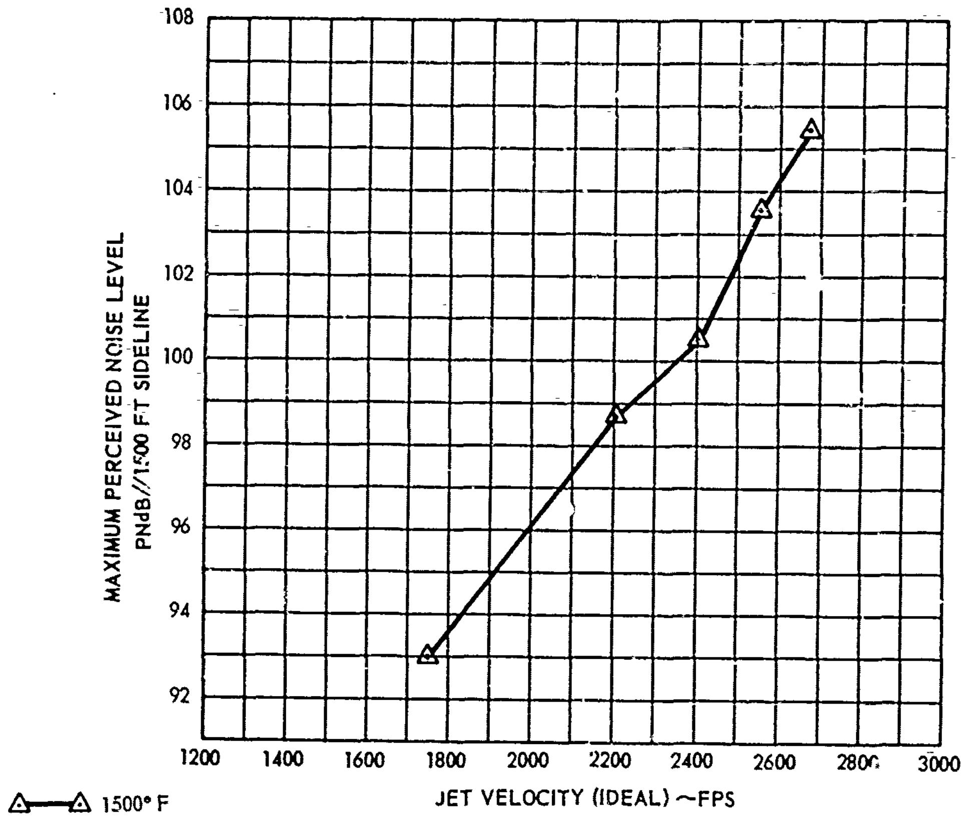


△—△ 1500° F

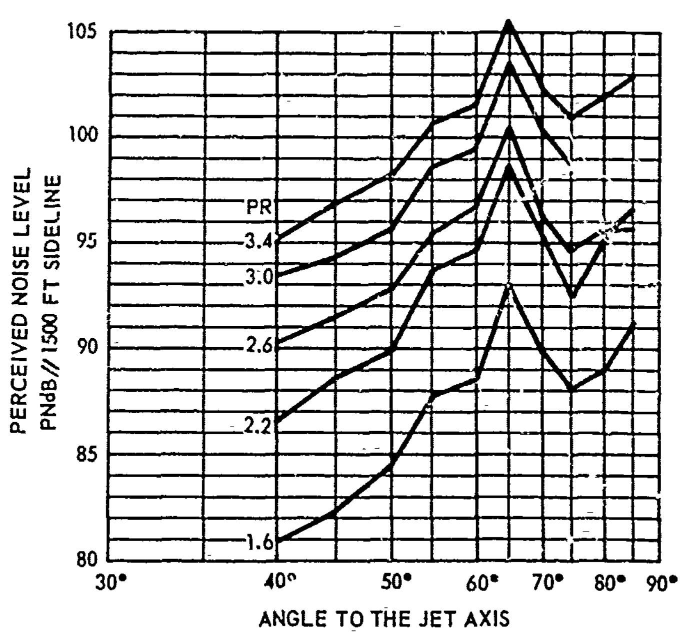
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

HM-AP-59-A NOZZLE
(42 TUBES, 12 LOBE SPOKE ENDS, ANNULAR ARRAY)
AR 8.3
SCALE FACTOR: 8:1

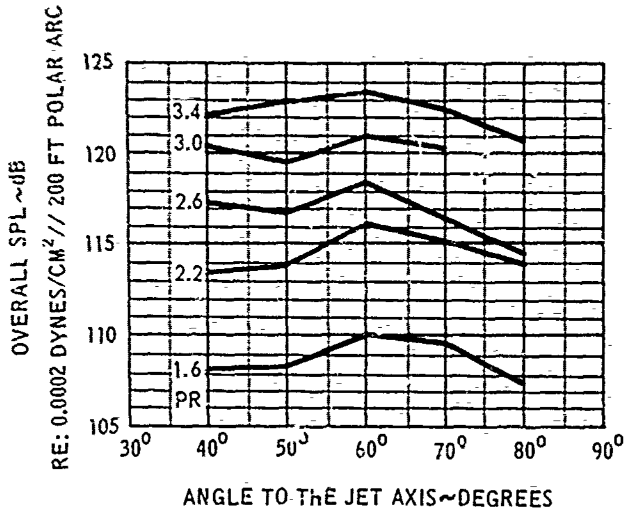


NOZZLE EXIT AREA (A_8): 12.6 FT²

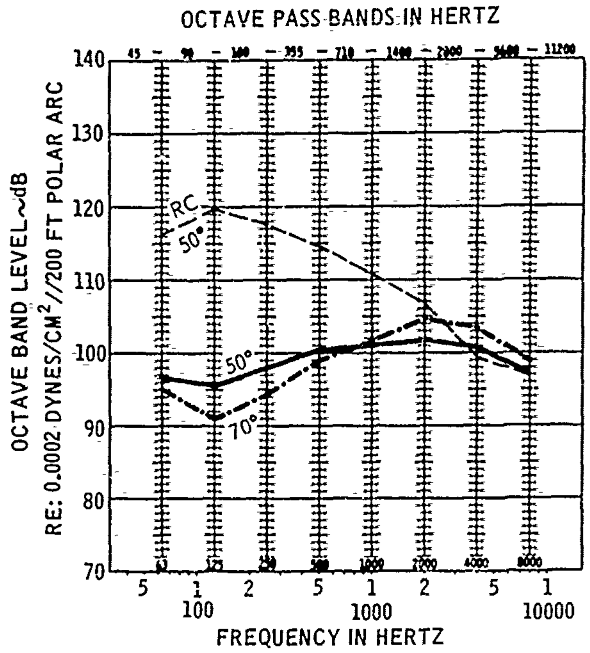


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

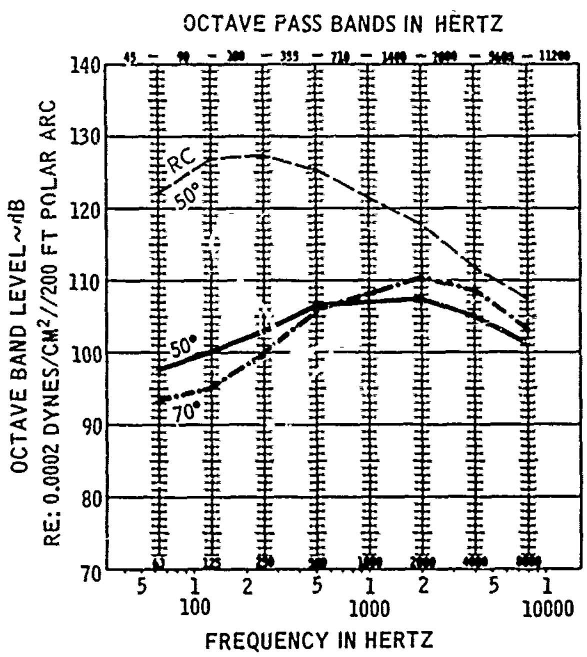


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT²

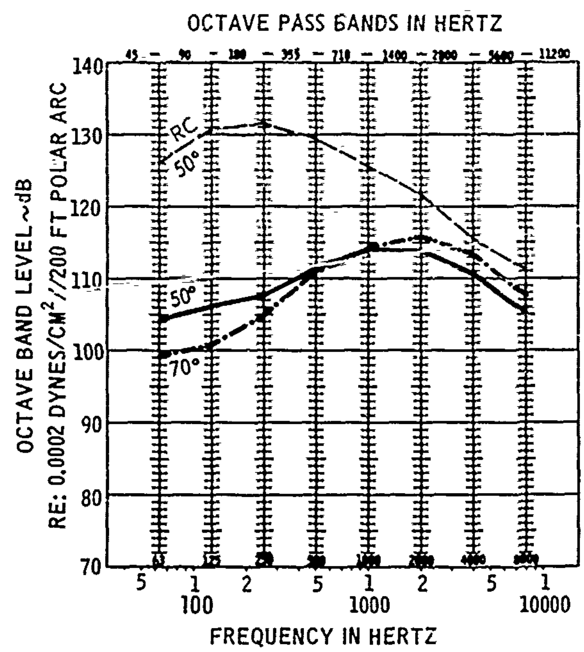


HM-AP-59-A NOZZLE
(42 TUBES, 12 LOBE SPOKE ENDS, ANNULAR ARRAY)
AR 8.3
SCALE FACTOR: 8:1

PRESSURE RATIO: 1.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1750 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

HM-AP-59-A NOZZLE

(42 Tube Annulus Array, Two Rows of Tubes)

Remarks

The HM-AP-59-A Nozzle tests indicated that a two row annulus array of 42 tubes does not approach the degree of noise suppression that can be attained with a hexagonal array of 37 tubes (HM-AP-41). The annulus configuration had a peak suppression value of 11 PNdB while the hexagonal array had a peak value of 17 PNdB. See Reference D28.

HM-AP-59-A NOZZLE

Test Facility: HNTF

Date:

T_{amb}:

R.H.:

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
25.1	1.6	1500°F	1750 fps	HM-AP-59-A
25.2	2.2	"	2202	"
25.3	2.6	"	2402	"
25.4	3.0	"	2555	"
25.5	3.4	"	2678	"
14.1	1.6	1500°F	1750	4.1 Inch Round Convergnt Nozzle
14.2	2.2	"	2202	"
14.3	2.6	"	2402	"
14.4	3.0	"	2555	"
14.5	3.4	"	2678	"

HM-AP-59-A NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2// 25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
25-1 L40	108.2	98.9	94.1	95.9	99.0	99.6	99.8	102.2	99.5
25-1 L45	107.7	96.4	95.7	96.8	99.1	99.9	101.1	100.7	95.6
25-1 L50	108.4	96.5	95.6	98.0	100.4	100.9	101.8	100.8	97.1
25-1 L55	110.4	100.5	95.0	99.0	101.9	103.7	103.5	102.6	98.5
25-1 L60	110.0	96.5	93.4	96.6	100.4	103.1	104.2	103.2	100.0
25-1 L65	113.4	93.5	91.6	95.6	100.6	104.1	109.2	108.8	101.6
25-1 L70	109.6	95.1	90.9	94.2	99.2	101.9	104.6	103.7	99.0
25-1 L75	107.6	93.2	89.3	93.6	98.7	101.2	102.5	100.3	95.7
25-1 L80	107.5	94.4	89.7	92.4	97.5	99.6	102.2	102.0	95.9
25-1 L85	109.5	95.2	88.6	93.0	97.8	101.6	105.8	104.5	100.3
25-2 L40	113.4	99.4	98.7	101.5	106.2	106.9	105.8	108.2	103.0
25-2 L45	114.0	99.1	99.8	102.1	106.6	107.5	107.7	106.3	100.6
25-2 L50	113.8	97.5	100.1	103.0	106.6	107.2	107.5	105.4	101.2
25-2 L55	116.4	98.1	99.5	104.4	108.8	110.4	110.0	108.8	104.5
25-2 L60	116.2	96.1	98.0	102.8	107.9	110.2	110.5	108.8	105.3
25-2 L65	119.3	94.1	[illegible]	101.5	107.3	110.8	115.3	114.2	106.6
25-2 L70	115.1	93.3	94.9	99.7	105.5	108.2	110.5	108.8	103.3
25-2 L75	113.3	91.1	93.2	96.6	104.8	107.5	108.4	105.4	100.4
25-2 L80	113.9	91.4	92.6	97.3	103.6	105.8	106.9	108.8	103.0
25-2 L85	114.8	90.9	92.9	97.8	104.1	107.5	109.5	109.6	104.9
25-3 L40	117.3	103.4	102.2	104.0	109.3	111.4	110.2	110.1	106.2
25-3 L45	116.9	102.5	103.0	104.4	109.2	111.0	110.9	108.9	102.4
25-3 L50	116.7	101.2	103.3	105.3	109.3	110.7	110.6	107.9	102.8
25-3 L55	118.1	101.8	102.8	106.6	111.0	112.4	111.7	109.7	104.8
25-3 L60	118.5	92.2	101.2	105.1	110.2	112.9	112.7	110.7	106.6
25-3 L65	121.2	97.2	99.6	103.8	109.9	113.6	117.3	115.5	107.5
25-3 L70	116.4	96.4	98.1	102.0	107.8	110.3	111.5	109.1	103.1
25-3 L75	114.5	94.1	96.3	100.6	106.6	109.1	109.5	106.1	100.5
25-3 L80	114.4	94.4	95.5	99.4	95.3	107.6	109.9	109.0	103.0
25-3 L85	113.7	94.0	95.4	99.8	105.3	108.6	99.9	109.0	103.7
25-4 L40	120.3	106.6	104.8	106.5	111.6	114.5	113.6	113.4	109.0
25-4 L45	119.5	105.6	105.5	106.6	111.1	114.2	113.8	110.7	103.2
25-4 L50	119.5	104.2	105.9	107.4	111.5	114.0	113.8	110.6	105.2
25-4 L55	121.2	104.8	105.1	109.4	113.4	115.7	115.1	112.8	107.8
25-4 L60	121.1	101.9	103.5	107.8	113.1	116.1	115.2	112.7	108.6
25-4 L65	124.2	100.2	102.2	106.7	112.8	117.0	120.3	118.5	110.4
25-4 L70	120.4	99.0	100.6	104.7	110.9	114.3	115.7	113.4	107.7
25-4 L75	118.8	96.9	99.2	104.0	110.3	113.6	113.9	110.1	104.5
25-4 L80	~~120.1~~	~~106.9~~	~~108.2~~	~~112.4~~	~~118.4~~	~~121.1~~	~~123.3~~	~~122.1~~	~~115.6~~
25-4 L85	~~120.4~~	~~106.3~~	~~107.9~~	~~112.4~~	~~118.1~~	~~121.8~~	~~123.3~~	~~122.6~~	~~117.2~~
25-5 L40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	115.0	[illegible]
25-5 L45	122.2	108.4	107.8	108.7	113.2	116.8	117.0	113.7	106.5
25-5 L50	121.9	106.7	107.9	108.8	113.3	116.5	116.5	112.9	107.2
25-5 L55	123.2	107.5	107.5	111.1	114.9	117.9	117.4	114.7	109.4
25-5 L60	123.4	104.0	105.9	110.1	115.2	118.2	117.7	115.1	110.8
25-5 L65	125.2	102.3	104.3	108.4	114.6	119.5	122.3	120.1	112.0
25-5 L70	122.6	101.2	102.9	106.8	113.0	116.9	118.1	115.2	109.1
25-5 L75	120.9	98.9	101.3	105.7	112.2	115.8	116.2	112.1	106.2
25-5 L80	120.8	99.4	100.5	104.3	110.4	114.0	116.2	114.8	108.0
25-5 L85	121.3	98.8	100.3	104.6	110.6	114.9	116.3	115.5	109.9

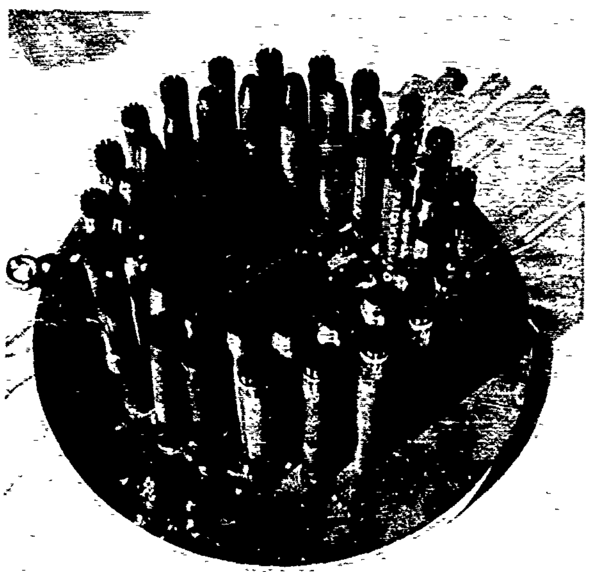
NOTE: THESE ARE FREE FIELD VALUES

HM-AP-59-A NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
14-1 L40	125.0	118.6	120.5	118.8	115.6	111.6	105.6	100.8	98.9
14-1 L45	126.3	121.2	122.1	119.0	115.3	111.5	107.0	100.4	100.5
14-1 L50	123.8	116.0	119.7	117.7	114.7	111.2	107.1	99.5	96.8
14-1 L55	123.3	114.2	117.9	117.9	115.5	112.8	109.3	102.5	97.6
14-1 L60	121.0	113.4	114.6	115.0	114.3	112.3	108.6	101.7	96.2
14-1 L65	120.8	110.0	112.8	114.5	115.1	113.0	108.7	103.2	95.6
14-1 L70	118.3	108.3	110.0	111.6	112.3	111.1	107.3	102.3	93.8
14-1 L75	117.0	105.4	109.2	110.5	111.2	109.9	108.4	99.3	91.9
14-1 L80	115.9	106.4	106.4	108.4	110.1	109.1	105.5	100.2	93.0
14-1 L85	116.7	107.1	107.4	109.4	110.5	110.1	106.5	101.7	94.6
14-2 L40	132.9	125.1	126.8	127.5	125.7	121.9	116.9	113.6	109.8
14-2 L45	134.5	127.6	129.2	128.2	126.4	122.8	119.1	114.2	110.7
14-2 L50	132.5	122.1	126.8	127.4	125.4	121.6	118.2	112.0	107.4
14-2 L55	132.1	119.9	125.4	127.3	125.2	122.4	119.6	114.0	109.0
14-2 L60	129.4	115.9	121.9	123.9	123.0	121.3	118.2	112.5	107.6
14-2 L65	128.1	114.5	118.8	121.9	122.7	120.9	117.0	112.8	106.0
14-2 L70	125.8	112.7	115.6	118.7	120.2	119.5	116.4	111.6	102.7
14-2 L75	124.4	110.0	114.0	117.5	118.8	118.1	115.2	108.8	101.1
14-2 L80	123.1	110.8	112.1	115.2	117.2	117.0	114.2	110.1	102.9
14-2 L85	123.7	111.3	112.4	115.8	117.7	118.0	115.0	110.7	103.4
14-3 L40	135.1	127.3	129.1	129.7	127.4	124.0	119.3	116.2	112.3
14-3 L45	136.9	130.2	131.6	130.6	128.4	125.0	121.2	116.4	113.1
14-3 L50	135.5	124.6	129.3	130.5	129.0	125.3	122.0	116.0	111.4
14-3 L55	135.1	121.7	127.5	130.2	128.7	126.1	123.6	118.3	113.6
14-3 L60	132.5	118.3	124.5	126.9	126.4	124.6	121.8	116.5	112.0
14-3 L65	130.7	116.2	121.1	124.1	125.4	123.8	120.5	116.8	110.3
14-3 L70	129.2	114.7	118.3	121.6	123.4	123.2	120.6	116.5	108.3
14-3 L75	127.4	111.8	116.1	119.8	121.8	121.7	118.8	112.7	105.2
14-3 L80	126.2	112.4	114.4	117.5	120.1	120.9	117.8	113.8	106.8
14-3 L85	126.9	113.0	114.3	117.7	121.0	121.7	118.7	114.9	108.2
14-4 L40	135.6	128.9	130.1	130.1	126.9	123.3	118.0	114.3	111.3
14-4 L45	137.6	131.4	132.7	131.4	128.5	124.8	120.7	115.4	113.1
14-4 L50	136.4	126.0	130.5	131.4	129.6	125.7	121.8	115.5	111.3
14-4 L55	136.4	123.3	129.0	131.6	130.1	127.2	124.0	118.2	113.5
14-4 L60	133.4	119.4	125.9	128.1	127.4	125.0	121.3	115.2	110.3
14-4 L65	132.3	118.9	123.1	126.1	127.2	125.0	120.9	116.2	109.4
14-4 L70	129.8	116.2	119.4	122.5	124.2	123.7	120.2	115.2	106.5
14-4 L75	128.7	113.3	117.2	121.1	123.5	123.0	119.4	112.9	105.3
14-4 L80	128.0	113.7	115.5	119.1	122.5	122.9	119.3	115.0	107.9
14-4 L85	128.9	114.3	115.3	119.7	123.7	123.7	120.4	116.2	109.5
14-5 L40	138.1	131.5	132.6	132.2	129.3	126.1	121.6	118.8	115.6
14-5 L45	[illegible]	134.1	[illegible]	[illegible]	[illegible]	127.5	[illegible]	[illegible]	[illegible]
14-5 L50	138.7	128.2	132.9	133.7	131.6	128.1	124.7	118.9	114.5
14-5 L55	139.2	125.5	131.6	134.2	133.0	130.2	127.7	122.7	118.6
14-5 L60	135.6	120.9	127.7	130.0	129.6	127.5	124.6	119.3	114.9
14-5 L65	134.5	120.3	124.5	127.7	129.1	127.8	124.4	120.8	114.7
14-5 L70	132.3	117.7	120.7	124.4	126.5	126.6	123.5	119.4	111.1
14-5 L75	131.3	114.9	118.7	123.1	126.0	126.0	122.8	117.3	110.6
14-5 L80	130.6	115.3	117.3	121.1	125.0	125.5	122.4	118.9	112.6

NOTE: THESE ARE FREE FIELD VALUES

HM-AP-59-B NOZZLE
(42TUBES ANNULAR ARRAY,2ROWS of TUBES,AR 8.3)



Description:

The HM-AP-59B nozzle is a 42 tube annulus array with 21 tubes in the outer row and 21 tubes in the inner row. The tube terminations in the outer row are individual 12-spoke nozzles. The tubes in the inner row have round convergent ends.

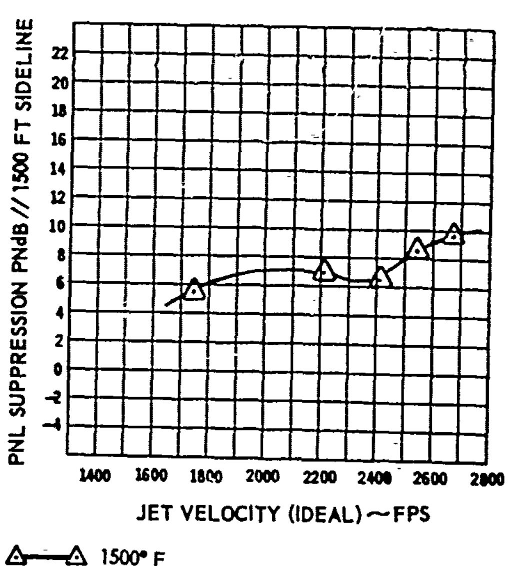
Number of Elements: 42
Area Ratio: 8.3
Tube Spacing (between inner and outer rows): 1.35 Inches
Flow Area: 15 Square Inches
Exit Cant Angle: 0 Degrees
Length of Tubes: 7 Inches

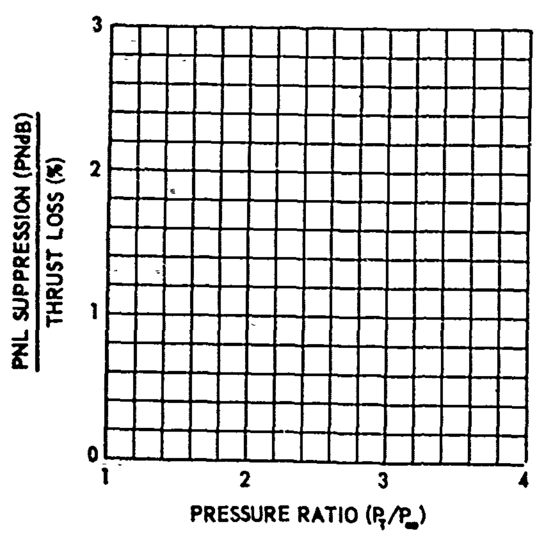
Tube Terminations:

a. Outer Row of 11 Tubes
   12 spokes with AR = 1.86
   75% spoke penetration
   0.92 inches outside diameter
   A_F = 0.357 square inches
   0 degree exit cant angle
   77 degree ventilation gutter cant angle

b. Inner Row of 11 Tubes
   0.674 inch diameter flow exit
   0.63 inch long convergent section

Material: 321 CRES

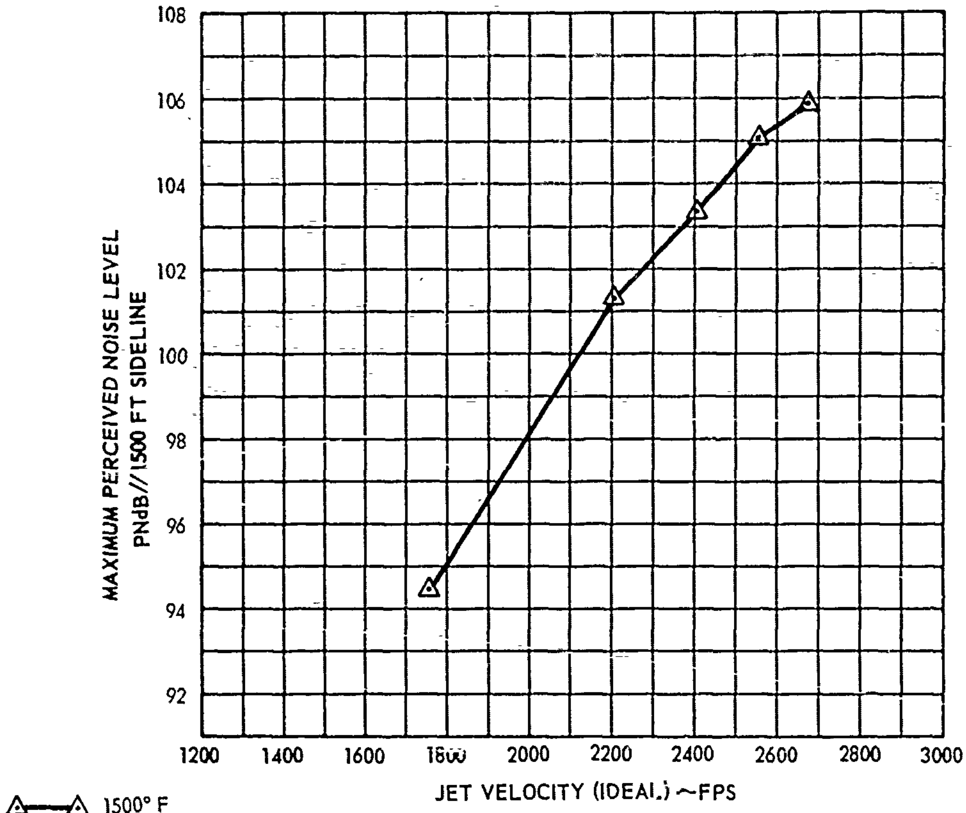




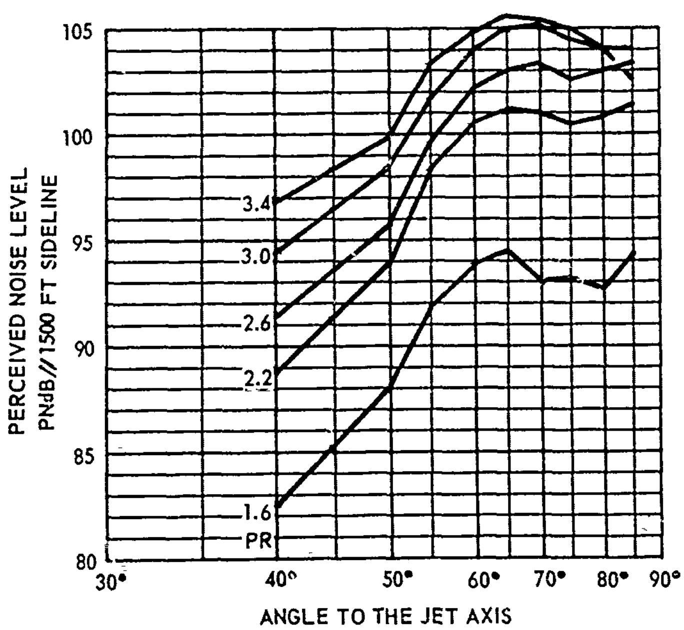
NOZZLE EXIT AREA (A_J): 12.6 FT^2

FREE FIELD VALUES

HM-AP-59-B NOZZLE
(42 TUBE ANNULAR ARRAY, 2 ROWS OF TUBES)
AR 8.3, SCALE FACTOR: 8:1



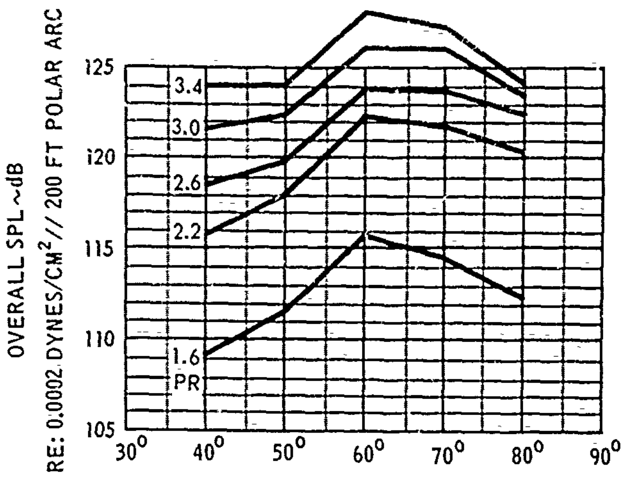
NOZZLE EXIT AREA (A_8): 12.6 FT^2



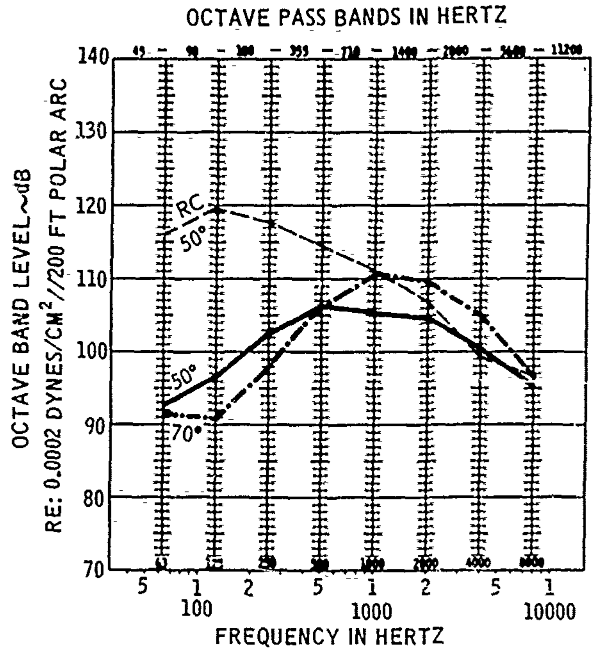
TOTAL TEMPERATURE (T_8): 1500° F

NOZZLE EXIT AREA (A_8): 12.6 FT^2

FREE FIELD VALUES

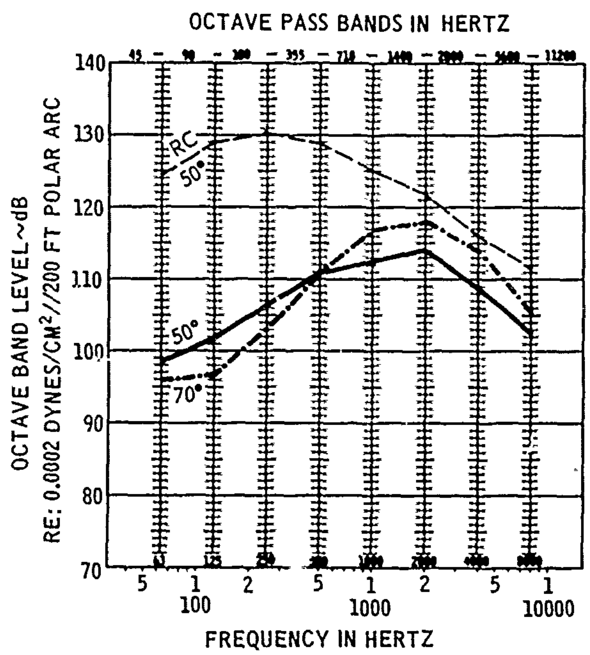


ANGLE TO THE JET AXIS~DEGREES
TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT²

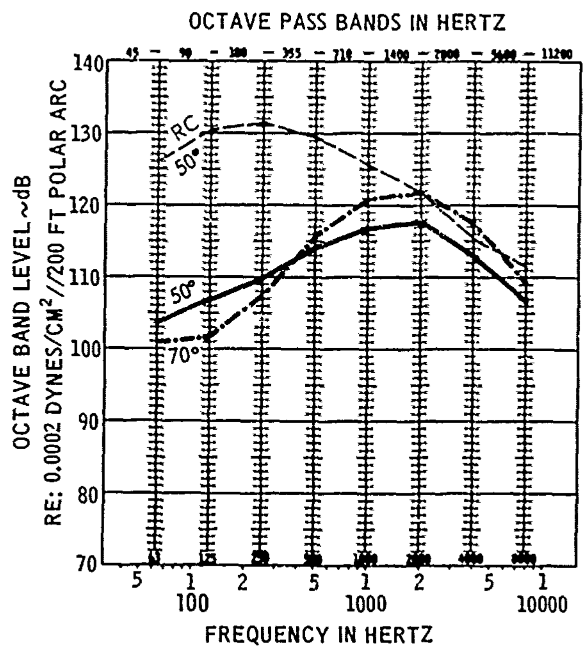


HM-AP-59-B NOZZLE
(42 TUBE ANNULAR ARRAY, 2 ROWS OF TUBES)
AR 8.3
SCALE FACTOR: 8:1

PRESSURE RATIO: 1.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1750 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

HM-AP-59-B NOZZLE

(42 Tube Annular Array, Two Rows of Tubes)

Remarks

This nozzle consisting of equal numbers of 12-lobe spokes and round convergent nozzle terminated tubes. The jet noise suppression characteristics are about 2 PNdB (or dB) less when compared to the case where all tubes had 12-lobe spoke ends (HM-AP-59-A Nozzle). Neither nozzle approached the degree of suppression attained by a 37 tube, 12-spoke ends, hexagon array (HM-AP-41). See Reference. D28.

HM-AP-59-B NOZZLE

Test Facility: HNTF

Date:

Temp.:

R.H.:

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
26.1	1.6	1500°F	1750 fps	HM-AP-59-B
26.2	2.2	"	2202	"
26.3	2.6	"	2402	"
26.4	3.0	"	2555	"
26.5	3.4	"	2678	"
14.1	1.6	1500°F	1750 fps	4.1 Inch Round Convergent Nozzle
14.2	2.2	"	2202	"
14.3	2.6	"	2402	"
14.4	3.0	"	2555	"
14.5	3.4	"	2678	"

HM-AP-59-B NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2// 25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
26-1 L40	109.2	93.4	95.4	99.8	102.6	102.1	100.8	101.2	98.9
26-1 L45	110.4	92.9	96.5	101.1	104.1	103.8	103.3	101.8	98.7
26-1 L50	111.6	92.4	96.7	102.6	106.2	105.4	104.7	100.6	98.8
26-1 L55	114.8	91.5	95.9	103.1	108.5	110.1	108.0	104.6	99.1
26-1 L60	115.9	93.7	93.9	101.5	108.0	111.8	110.2	105.8	100.7
26-1 L65	115.7	89.9	92.8	100.4	108.2	111.1	110.1	107.1	100.0
26-1 L70	114.5	91.3	90.8	97.9	106.0	110.3	109.6	105.2	98.5
26-1 L75	113.5	87.4	89.0	97.0	105.1	108.9	109.1	103.8	98.5
26-1 L80	112.4	88.1	88.7	95.3	102.9	107.6	107.5	104.8	97.5
26-2 L40	115.9	99.8	100.5	103.6	108.0	109.2	109.2	109.0	105.2
26-2 L45	116.8	98.8	101.2	104.7	109.1	110.6	111.3	109.0	102.1
26-2 L50	118.1	98.3	101.9	106.6	110.7	112.3	113.1	108.7	102.6
26-2 L55	121.2	97.4	101.3	107.8	113.5	116.1	115.8	112.7	106.5
26-2 L60	122.5	98.5	99.4	106.0	112.9	118.1	117.6	113.7	108.4
26-2 L65	122.3	95.3	98.1	104.9	113.2	117.2	117.4	115.0	108.6
26-2 L70	121.9	95.6	96.4	103.0	111.8	117.0	117.7	113.9	105.7
26-2 L75	120.7	92.8	94.6	101.8	110.6	115.6	116.8	111.9	104.9
26-2 L80	120.2	93.5	94.4	100.1	108.3	114.4	115.9	113.9	107.0
26-2 L85	120.3	92.5	94.0	100.2	108.1	114.2	115.8	114.3	108.3
26-3 L40	118.5	102.8	103.0	105.6	110.2	112.4	112.1	111.5	106.9
26-3 L45	119.0	102.0	103.7	106.5	111.0	113.3	113.5	111.2	103.5
26-3 L50	119.8	101.1	104.3	107.9	112.1	114.1	114.7	110.4	104.0
26-3 L55	122.5	100.0	103.9	109.9	115.1	117.0	117.0	114.2	107.9
26-3 L60	124.0	100.8	102.0	108.3	115.1	119.4	119.0	115.4	110.4
26-3 L65	124.3	98.2	101.0	107.1	115.0	119.3	119.3	116.7	110.4
26-3 L70	123.9	98.4	99.2	105.1	113.7	118.9	119.9	115.8	107.9
26-3 L75	122.9	95.3	97.3	104.2	113.0	118.0	119.0	113.7	106.7
26-3 L80	122.5	95.8	96.8	102.4	110.8	116.0	118.2	116.0	109.2
26-3 L85	122.4	95.1	96.5	[illegible]	110.3	[illegible]	118.1	[illegible]	[illegible]
26-4 L40	121.6	105.7	105.9	107.9	112.2	115.5	115.9	114.8	110.0
26-4 L45	122.1	104.7	106.3	108.6	113.0	116.3	117.2	114.3	106.6
26-4 L50	122.4	103.7	106.9	109.7	114.1	116.8	117.7	112.9	106.7
26-4 L55	124.8	102.4	106.3	111.7	116.4	119.3	119.7	116.6	110.5
26-4 L60	125.9	102.8	104.5	110.2	116.8	121.2	121.0	117.2	112.6
26-4 L65	126.2	103.4	103.4	108.9	116.6	121.2	121.4	118.7	112.8
26-4 L70	125.8	100.9	101.7	107.4	115.4	120.9	121.8	117.3	109.6
26-4 L75	124.8	97.6	99.7	106.1	114.9	119.8	121.0	115.5	108.6
26-4 L80	123.6	98.1	99.3	104.4	112.1	116.1	119.4	116.6	109.6
26-4 L85	122.0	97.3	98.7	103.7	110.8	116.6	117.8	114.8	108.1
26-5 L40	124.0	108.5	107.8	109.6	114.0	118.0	118.7	117.0	112.6
26-5 L45	123.9	107.2	108.0	110.1	114.3	118.2	119.2	115.9	108.5
26-5 L50	124.0	106.0	108.6	111.0	115.4	118.6	119.5	114.2	108.2
26-5 L55	126.0	104.5	108.1	113.1	117	120.7	121.1	117.6	111.8
26-5 L60	126.8	104.6	106.2	112.0	[illegible]	122.0	121.7	117.8	113.1
26-5 L65	127.0	102.2	105.2	110.9	117.8	122.2	121.9	119.1	113.2
26-5 L70	126.2	102.5	103.5	108.6	116.2	121.4	122.1	117.1	109.2
26-5 L75	125.2	99.5	101.5	107.7	115.9	120.4	121.2	115.1	108.1
26-5 L80	124.1	99.9	101.0	105.7	113.2	119.1	119.8	116.5	109.3
26-5 L85	123.3	99.4	100.4	105.0	111.9	118.2	119.1	115.9	109.1

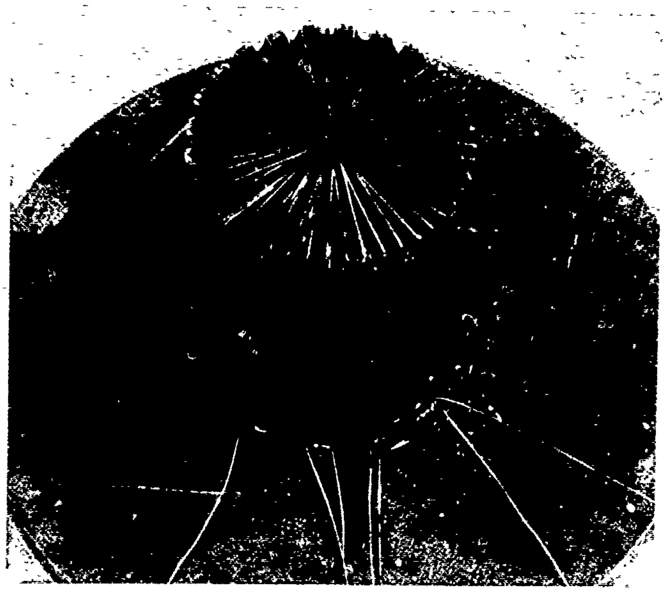
NOTE: THESE ARE FREE FIELD VALUES

HM-AP-59-B NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
14-1 L40	125.0	118.6	120.5	118.8	115.6	111.6	105.6	100.8	98.9
14-1 L45	126.3	121.2	122.1	119.0	115.3	111.5	107.0	100.4	100.5
14-1 L50	123.8	116.0	119.7	117.7	114.7	111.2	107.1	99.5	96.8
14-1 L55	123.3	114.2	117.9	117.9	115.5	112.8	109.3	102.5	97.6
14-1 L60	121.0	110.4	114.0	115.0	114.3	112.3	108.6	101.7	96.2
14-1 L65	120.8	110.0	112.8	114.5	115.1	113.0	108.7	103.2	95.6
14-1 L70	118.3	108.3	110.0	111.6	112.3	111.1	107.3	102.3	93.8
14-1 L75	117.0	105.4	108.2	110.5	111.2	109.9	106.4	99.3	91.9
14-1 L80	115.9	106.4	106.4	108.4	110.1	109.1	105.5	100.2	93.0
14-1 L85	116.7	107.1	107.4	109.4	110.5	110.1	106.5	101.7	94.6
14-2 L40	132.9	125.1	125.8	127.5	125.7	121.9	116.9	113.6	109.8
14-2 L45	134.5	127.8	129.2	128.2	126.4	122.8	119.1	114.2	110.7
14-2 L50	132.5	122.1	126.8	127.4	125.4	121.6	118.2	112.0	107.4
14-2 L55	132.1	119.9	125.4	127.3	125.2	122.4	119.6	114.0	109.0
14-2 L60	129.4	115.9	121.9	123.9	123.0	121.3	118.2	112.5	107.6
14-2 L65	128.1	114.5	118.8	121.9	122.7	120.9	117.0	112.8	106.0
14-2 L70	125.8	112.7	115.6	118.7	120.2	119.5	116.4	111.6	102.7
14-2 L75	124.4	110.0	114.0	117.5	118.8	118.1	115.2	108.8	101.1
14-2 L80	123.1	110.8	112.1	115.2	117.2	117.0	114.2	110.1	102.9
14-2 L85	123.7	111.3	112.4	115.8	117.7	118.0	115.0	110.7	103.4
14-3 L40	135.1	127.3	129.1	129.7	127.4	124.0	119.3	116.2	112.3
14-3 L45	136.9	130.2	131.6	130.6	128.4	125.0	121.2	116.4	113.1
14-3 L50	135.5	124.6	129.3	130.3	129.0	125.3	122.0	116.0	111.4
14-3 L55	135.1	121.7	127.5	130.2	128.7	126.1	123.6	118.3	113.6
14-3 L60	132.5	118.3	124.5	126.9	126.4	124.6	121.8	116.5	112.0
14-3 L65	130.7	116.2	121.1	124.1	125.4	123.8	120.5	116.8	110.3
14-3 L70	129.2	114.7	118.3	121.6	123.4	123.2	120.6	115.5	108.3
14-3 L75	127.4	111.8	116.1	119.8	121.8	121.7	118.8	112.7	105.2
14-3 L80	126.2	112.4	114.4	117.5	120.1	120.9	117.8	113.8	106.8
14-3 L85	126.9	113.0	114.3	117.7	121.0	121.7	118.7	114.9	108.2
14-4 L40	135.6	128.9	130.1	130.1	126.9	123.3	118.0	114.3	111.3
14-4 L45	137.6	131.4	132.7	131.4	128.5	124.8	120.7	115.4	113.1
14-4 L50	136.4	126.0	130.5	131.4	129.6	125.7	121.8	115.5	111.3
14-4 L55	136.4	123.3	129.0	131.6	130.1	127.2	124.0	118.2	113.5
14-4 L60	133.4	119.4	125.9	128.1	127.4	125.0	121.3	115.2	110.3
14-4 L65	132.3	118.9	123.1	126.1	127.2	125.0	120.9	116.2	109.4
14-4 L70	129.8	116.2	119.4	122.5	124.2	123.7	120.2	115.2	106.5
14-4 L75	128.7	113.3	117.2	121.1	123.5	123.0	119.4	112.9	105.3
14-4 L80	128.0	113.7	115.5	119.1	122.5	122.9	119.3	115.0	107.9
14-4 L85	128.9	114.3	115.3	119.7	123.7	123.7	120.4	116.2	109.5
14-5 L40	138.1	131.5	132.6	132.2	129.3	126.1	121.6	118.8	115.6
14-5 L45	140.1	134.1	135.2	133.6	130.7	127.5	124.1	119.8	116.6
14-5 L50	138.7	128.2	132.9	133.7	131.6	128.1	124.7	118.9	114.5
14-5 L55	139.2	125.5	131.6	134.2	133.0	130.2	127.7	122.7	118.6
14-5 L60	135.6	120.9	127.7	130.0	129.6	127.5	124.6	119.3	114.9
14-5 L65	134.5	120.3	124.5	127.7	129.1	127.8	124.4	120.8	114.7
14-5 L70	132.3	117.7	120.7	124.4	126.5	125.6	123.5	119.4	111.1
14-5 L75	131.3	114.9	118.7	123.1	126.0	126.0	122.8	117.3	110.6
14-5 L80	130.6	115.3	117.3	121.1	125.0	125.5	122.4	118.9	112.6
14-5 L85	131.7	115.7	116.6	121.6	126.5	126.4	123.5	120.1	114.5

NOTE: THESE ARE FREE FIELD VALUES

HM-AP-60 NOZZLE
(24 SPOKES, AR 2.0)



Description:

The HM-AP-60 nozzle is a 24-spoke nozzle designed to install on a baseplate and be used in conjunction with various multi-tube arrangements. The HM-AP-60 nozzle was used as the central flow element in the HM-AP-61A suppressor nozzle configurations.

Number of Elements: 24 spokes

Area Ratio: 2.0

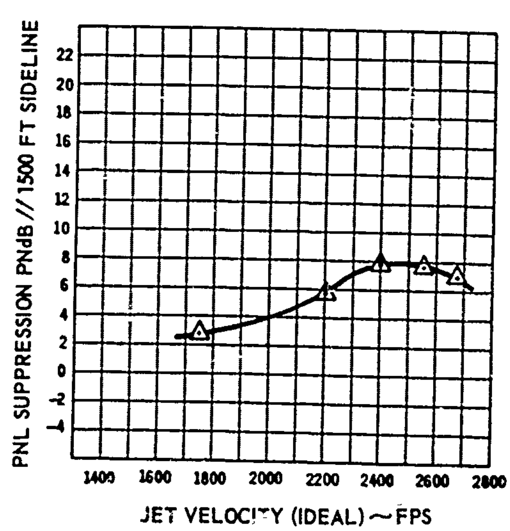
Spoke Penetration: 90%

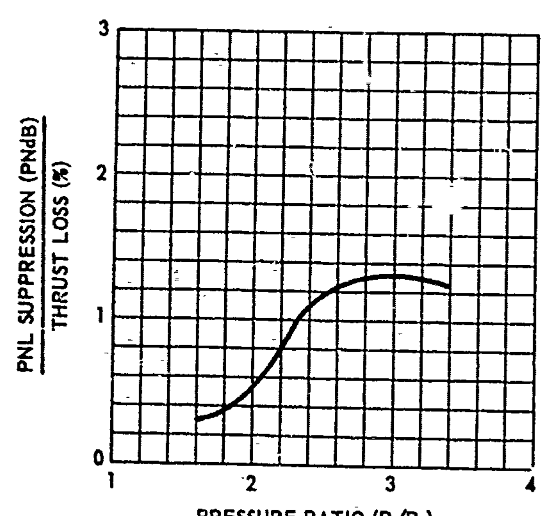
Flow Area: 13.2 square inches

Exit Cant Angle: 0 degrees

Ventilation Gutter Cant Angle: 20 degrees

Material: 321 CRES

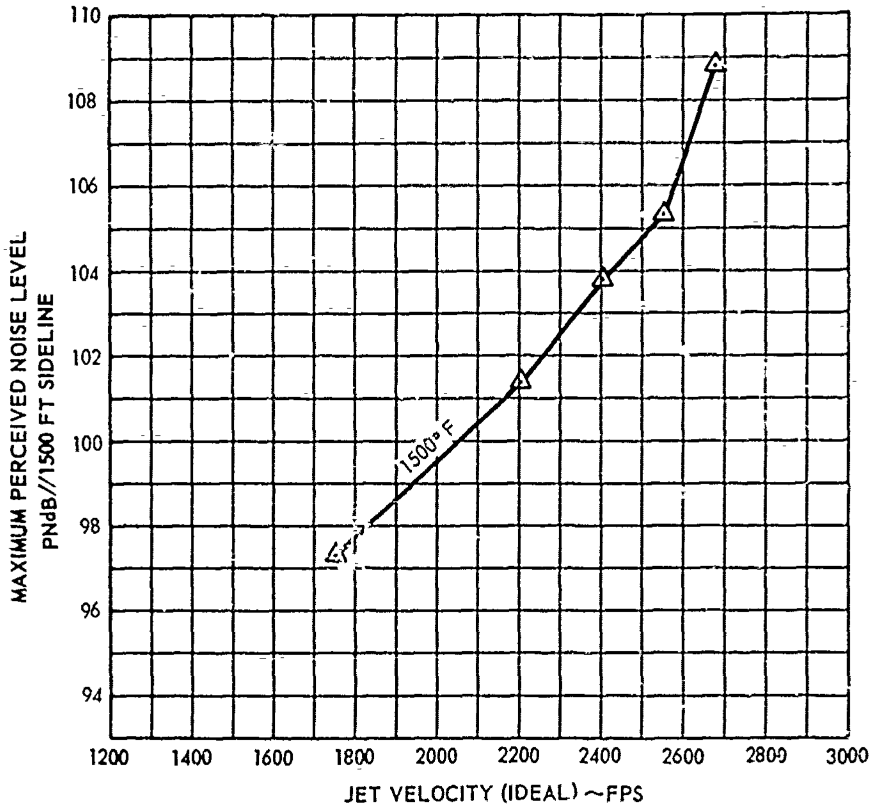




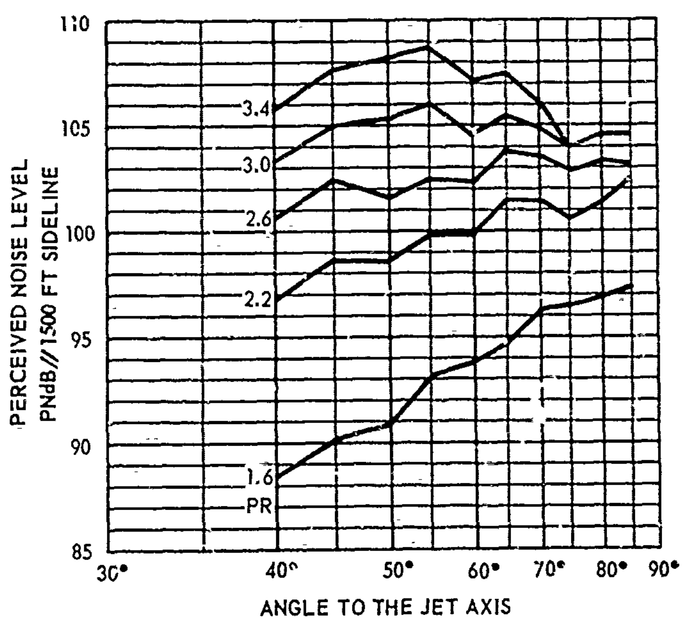
NOZZLE EXIT AREA (A_8): 12.6 FT^2

FREE FIELD VALUES

HM-AP-60 NOZZLE
(24 SPOKES)
AR 2.0
SCALE FACTOR: 8:1

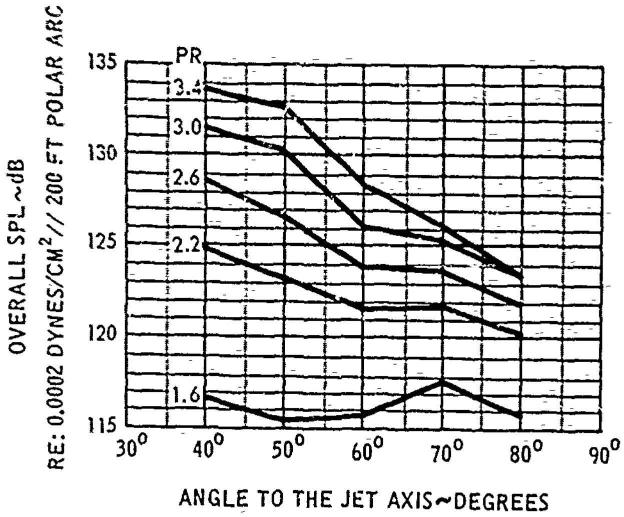


NOZZLE EXIT AREA (A_8): 12.6 FT²

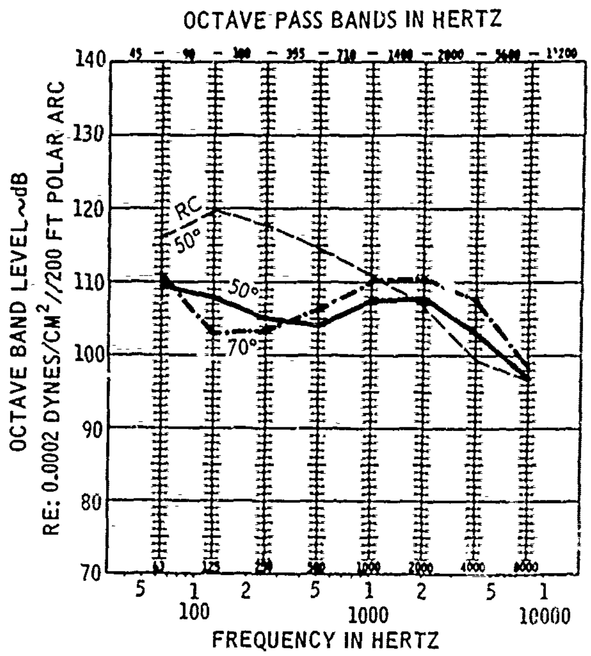


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

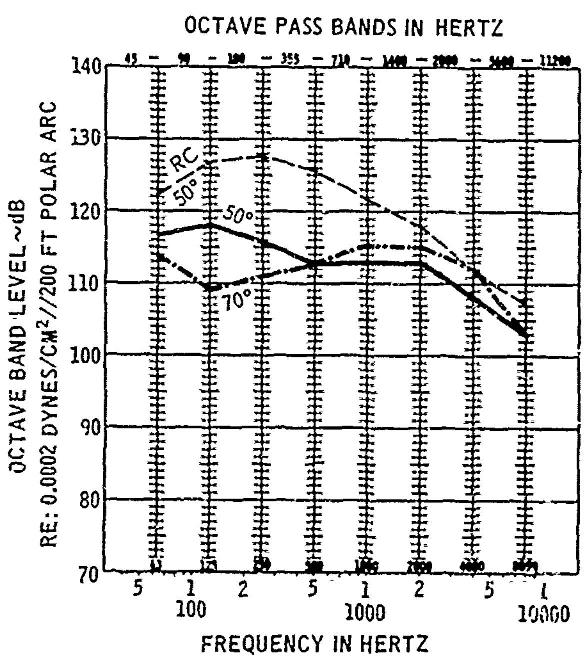


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8) : 12.6 FT²

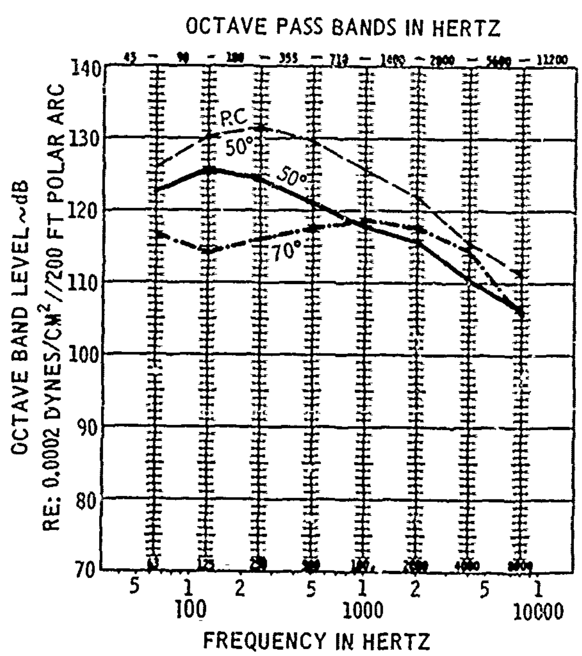


PRESSURE RATIO: 1.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1750 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²

HM-AP-60 NOZZLE
(24 SPOKES)
AR 2.0
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

HM-AP-60 NOZZLE

(24 Spokes, 2.0 Area Ratio)

Remarks

The HM-AP-60 Nozzle was tested with and without an ejector. The tight fitting unlined ejector provided 2 to 6 dB suppression in the last five octave bands at PR = 3.0 and T_T = 1500°F. This additional suppression was attained with considerable thrust loss. See Reference D28.

HM-AP-60 NOZZLE

Test Facility: HNTF

Date:

T_{amb}:

R.H.:

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
7.1	1.6	1500°F	1750 fps	HM-AP-60
7.2	2.2	"	2202	"
7.3	2.6	"	2402	"
7.4	3.0	"	2555	"
7.5	3.4	"	2678	"
14.1	1.6	1500°F	1750	4.1 Inch Round Convergent Noz.
14.2	2.2	"	2202	"
14.3	2.6	"	2402	"
14.4	3.0	"	2555	"
14.5	3.4	"	2678	"

HM-AP-60 NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM²// 25 FT

RUN NO.		OASPL	500	1K	2K	4K	8K	16K	32K	64K
7-1	L40	116.8	113.5	109.6	103.2	102.4	106.9	106.5	103.6	97.7
7-1	L45	116.7	111.7	110.0	104.9	103.4	106.0	108.3	104.7	97.7
7-1	L50	115.4	109.3	107.9	104.9	103.9	107.8	107.9	103.1	96.7
7-1	L55	115.9	107.7	106.3	105.7	105.4	109.6	108.9	105.7	99.1
7-1	L60	115.5	107.4	105.1	104.7	105.7	109.3	108.6	105.1	99.5
7-1	L65	115.8	109.5	103.3	103.3	105.7	109.0	109.0	106.4	98.0
7-1	L70	116.8	111.1	102.9	103.3	106.2	109.9	110.2	107.4	98.5
7-1	L75	116.1	104.4	101.9	103.9	106.7	110.7	110.8	106.5	98.5
7-1	L80	115.8	104.8	100.7	102.2	105.5	110.2	110.5	108.0	100.7
7-1	L85	116.1	105.3	100.4	102.4	105.5	110.6	110.8	108.2	101.0
7-2	L40	124.9	120.6	120.3	115.1	110.6	111.9	111.8	110.0	105.0
7-2	L45	125.0	119.8	120.4	116.2	111.9	112.9	113.3	109.7	103.9
7-2	L50	123.3	116.7	118.1	115.7	112.4	112.8	112.7	108.2	102.6
7-2	L55	122.8	114.0	115.5	115.5	113.6	114.9	114.0	111.4	105.7
7-2	L60	121.6	112.1	112.9	113.0	113.0	114.7	113.9	110.4	105.2
7-2	L65	122.1	110.7	111.0	112.5	114.3	115.8	115.4	112.8	103.9
7-2	L70	121.7	113.8	109.5	110.9	112.7	115.2	115.1	112.1	103.2
7-2	L75	120.1	107.1	108.0	110.0	111.8	114.2	114.4	109.8	102.1
7-2	L80	120.1	107.7	106.8	108.6	110.7	113.7	114.6	112.0	105.6
7-2	L85	121.0	107.4	106.2	106.7	111.2	114.9	115.8	113.2	106.5
7-3	L40	128.7	124.1	124.5	120.5	115.2	114.0	112.8	110.7	106.7
7-3	L45	128.8	123.4	124.8	121.1	116.2	114.9	114.3	111.0	106.3
7-3	L50	126.6	119.5	122.3	120.0	116.4	114.3	113.4	108.9	104.0
7-3	L55	125.4	116.5	119.3	119.2	116.8	116.0	114.6	111.7	106.1
7-3	L60	123.9	113.8	116.4	116.5	116.0	116.2	115.1	111.7	106.6
7-3	L65	124.5	112.9	114.0	115.5	116.7	117.7	117.7	115.2	106.4
7-3	L70	123.8	115.4	112.1	113.6	115.6	117.6	116.7	113.6	105.1
7-3	L75	122.5	109.1	110.8	113.0	114.8	116.5	116.4	112.0	104.8
7-3	L80	122.0	109.6	109.8	111.4	113.2	115.6	116.3	113.5	107.0
7-3	L85	121.9	109.1	108.9	111.4	113.5	115.7	116.0	113.0	106.4
7-4	L40	131.5	126.4	127.0	124.4	119.7	116.6	114.1	112.0	108.7
7-4	L45	131.7	125.7	127.5	124.8	120.4	117.6	115.6	112.2	108.1
7-4	L50	130.1	122.5	125.5	124.2	120.7	117.6	115.[illegible]	110.5	105.9
7-4	L55	128.9	119.2	122.9	123.7	121.1	118.8	11[illegible].2	112.9	107.8
7-4	L60	126.1	115.3	119.0	119.7	119.2	117.9	115.7	111.9	106.9
7-4	L65	125.8	115.1	116.5	118.2	119.0	118.5	117.4	114.4	105.7
7-4	L70	125.2	116.8	114.1	116.0	117.3	118.6	117.7	114.3	105.9
7-4	L75	123.6	110.7	112.9	115.2	116.3	117.4	116.9	112.3	105.4
7-4	L80	123.4	111.1	111.6	113.2	114.9	117.0	117.2	114.8	108.8
7-4	L85	123.2	110.7	110.6	113.0	114.9	116.8	117.0	114.6	108.6
7-5	L40	133.7	128.0	129.1	127.3	123.1	119.0	115.1	112.6	109.8
7-5	L45	134.0	127.2	129.5	127.9	121.2	120.5	117.6	113.5	109.9
7-5	L50	132.8	123.9	123.0	127.4	124.2	120.8	117.7	112.5	108.5
7-5	L55	131.7	120.5	125.3	126.7	124.5	121.9	118.6	115.0	109.9
7-5	L60	128.7	116.8	121.1	122.7	122.2	120.7	117.9	114.1	109.3
7-5	L65	127.9	116.4	118.2	120.6	121.5	120.7	119.3	116.1	107.3
7-5	L70	126.2	117.6	115.6	117.6	118.8	119.5	118.2	114.5	105.7
7-5	L75	123.4	111.0	113.2	115.7	116.8	117.1	115.7	110.7	103.3
7-5	L80	123.5	112.1	113.1	114.5	115.7	117.1	116.3	113.8	107.4
7-5	L85	123.6	111.7	112.1	114.6	116.2	117.3	116.4	113.9	107.4

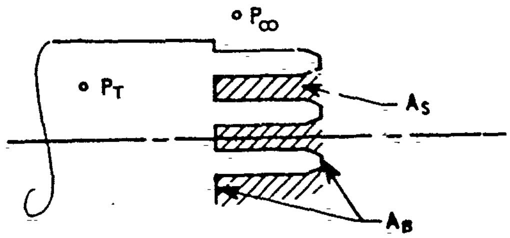
NOTE: THESE ARE FREE FIELD VALUES

NM-AP-60 NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
14-1 L40	125.0	118.6	120.5	118.8	115.6	111.6	105.6	100.8	98.9
14-1 L45	126.3	121.2	122.1	119.0	115.3	111.5	107.0	100.4	100.5
14-1 L50	123.8	116.0	119.7	117.7	114.7	111.2	107.1	99.5	96.8
14-1 L55	123.3	114.2	117.9	117.9	115.5	112.8	109.3	102.5	97.6
14-1 L60	121.0	110.4	114.6	115.0	114.3	112.3	108.6	101.7	96.2
14-1 L65	120.8	110.0	112.8	114.5	115.1	113.0	108.7	103.2	95.6
14-1 L70	118.3	108.3	110.0	111.6	112.3	111.1	107.3	102.3	93.8
14-1 L75	117.0	105.4	108.2	110.5	111.2	109.9	106.4	99.3	91.9
14-1 L80	115.9	106.4	106.4	108.4	110.1	109.1	105.5	100.2	93.0
14-1 L85	116.7	107.1	107.4	109.4	110.5	110.1	106.5	101.7	94.6
14-2 L40	132.9	125.1	126.8	127.5	125.7	121.9	116.9	113.6	109.8
14-2 L45	134.5	127.8	129.2	128.2	126.4	122.8	119.1	114.2	110.7
14-2 L50	132.5	122.1	126.8	127.4	125.4	121.6	118.2	112.0	107.4
14-2 L55	132.1	119.9	125.4	127.3	125.2	122.4	119.6	114.0	109.0
14-2 L60	129.4	115.9	121.9	123.9	123.0	121.3	118.2	112.5	107.6
14-2 L65	128.1	114.5	118.8	121.9	122.7	120.9	117.0	112.8	106.0
14-2 L70	125.8	112.7	115.6	118.7	120.2	119.5	116.4	111.6	102.7
14-2 L75	124.4	110.0	114.0	117.5	118.8	118.1	115.2	108.8	101.1
14-2 L80	123.1	110.8	112.1	115.2	117.2	117.0	114.2	110.1	102.9
14-2 L85	123.7	111.3	112.4	115.8	117.7	118.0	115.0	110.7	103.4
14-3 L40	135.1	127.3	129.1	129.7	127.4	124.0	119.3	116.2	112.3
14-3 L45	136.9	130.2	131.6	130.6	128.4	125.0	121.2	116.4	113.1
14-3 L50	135.5	124.6	129.3	130.3	129.0	125.3	122.0	116.0	111.4
14-3 L55	135.1	121.7	127.5	130.2	128.7	126.1	123.6	118.3	113.6
14-3 L60	132.5	118.3	124.5	126.9	126.4	124.6	121.8	116.5	112.0
14-3 L65	130.7	116.2	121.1	124.1	125.4	123.8	120.5	116.8	110.3
14-3 L70	129.2	114.7	118.3	121.6	123.4	123.2	120.6	116.5	108.3
14-3 L75	127.4	111.8	116.1	119.8	121.8	121.7	118.8	112.7	105.2
14-3 L80	126.2	112.4	114.4	117.5	120.1	120.9	117.8	113.8	106.8
14-3 L85	126.9	113.0	114.3	117.7	121.0	121.7	118.7	114.9	106.2
14-4 L40	135.6	128.9	130.1	130.1	126.9	123.3	118.0	114.3	111.3
14-4 L45	137.6	131.4	132.7	131.4	128.5	124.8	120.7	115.4	113.1
14-4 L50	136.4	126.0	130.5	131.4	129.6	125.7	121.8	115.5	111.3
14-4 L55	136.4	123.3	129.0	131.6	130.1	127.2	124.0	118.2	113.5
14-4 L60	133.4	119.4	125.9	128.1	127.4	125.0	121.3	115.2	110.3
14-4 L65	132.3	118.9	123.1	126.1	127.2	125.0	120.9	116.2	109.4
14-4 L70	129.8	116.2	119.4	122.5	124.2	123.7	120.2	115.2	106.5
14-4 L75	128.7	113.3	117.2	121.1	123.5	123.0	119.4	112.9	105.3
14-4 L80	128.0	113.7	115.5	119.1	122.5	122.9	119.3	115.0	107.9
14-4 L85	128.9	114.3	115.3	119.7	123.7	123.7	120.4	116.2	109.5
14-5 L40	138.1	131.5	132.6	132.2	129.3	126.1	121.6	118.8	115.6
14-5 L45	140.1	134.1	135.2	133.6	130.7	127.5	124.1	119.8	116.6
14-5 L50	138.7	128.2	132.9	133.7	131.6	128.1	124.7	118.9	114.5
14-5 L55	139.2	125.5	131.6	134.2	133.0	130.2	127.7	122.7	118.6
14-5 L60	135.6	120.9	127.7	130.0	129.6	127.5	124.6	119.3	114.9
14-5 L65	134.5	120.3	124.5	127.7	129.1	127.8	124.4	120.8	114.7
14-5 L70	132.3	117.7	120.7	124.4	126.5	126.6	123.5	119.4	111.1
14-5 L75	131.3	114.9	118.7	123.1	126.0	[illegible]	122.8	117.3	110.6
14-5 L80	130.6	115.3	117.3	121.1	125.0	125.5	122.4	118.9	112.6
14-5 L85	131.7	115.7	116.6	121.6	126.5	126.4	123.5	120.1	114.5

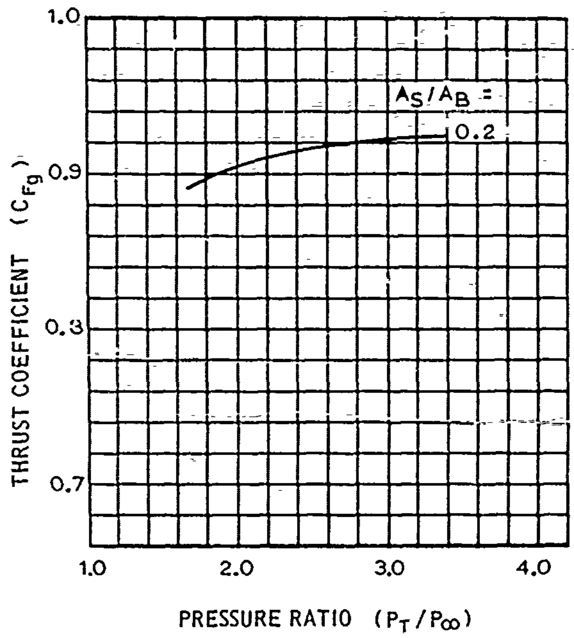
NOTE: THESE ARE FREE FIELD VALUES

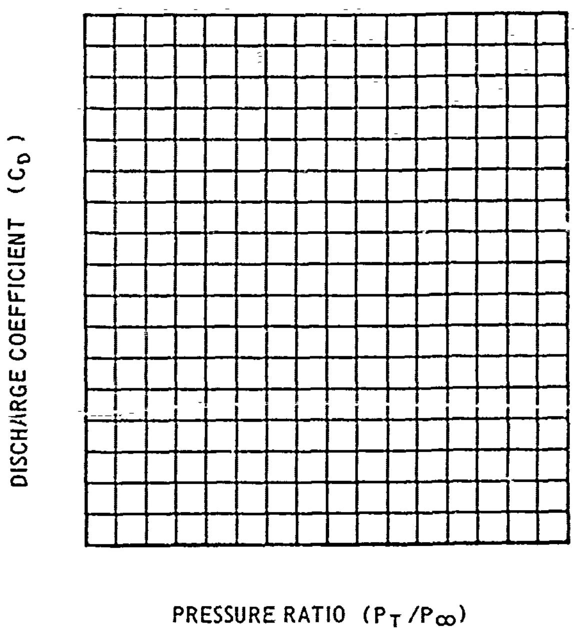
HM - AP - 60

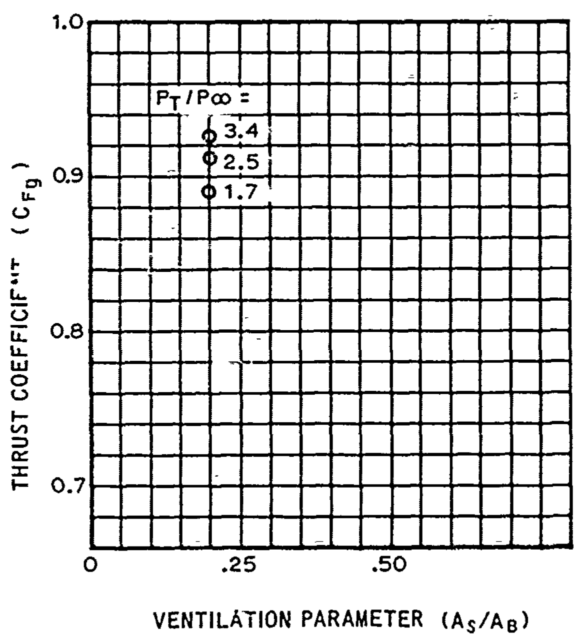


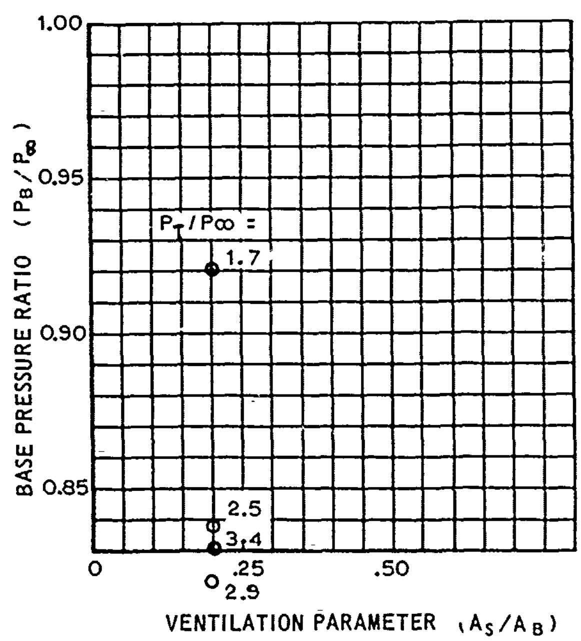
$$C_{Fg} = \frac{\text{(THRUST-DRAG) MEASURED}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{\text{(MASS FLOW) MEASURED}}{\text{IDEAL PRIMARY MASS FLOW}}$$









HM-AP-61-A NOZZLE

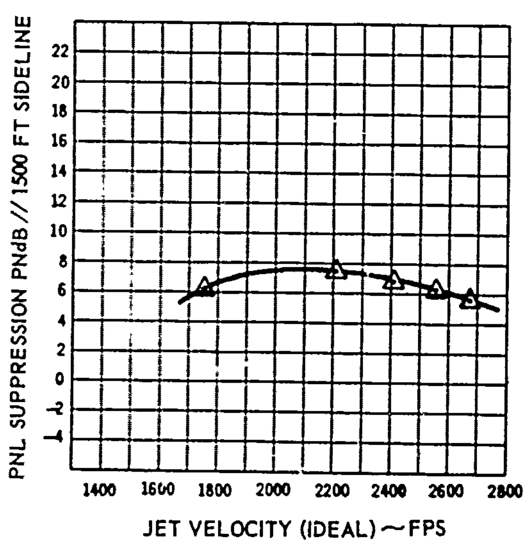
(42 TUBES, 6 CLUSTERS OF 7 TUBES EACH, AND A 24 SPOKE NOZZLE IN THE CENTER, AR5.2)

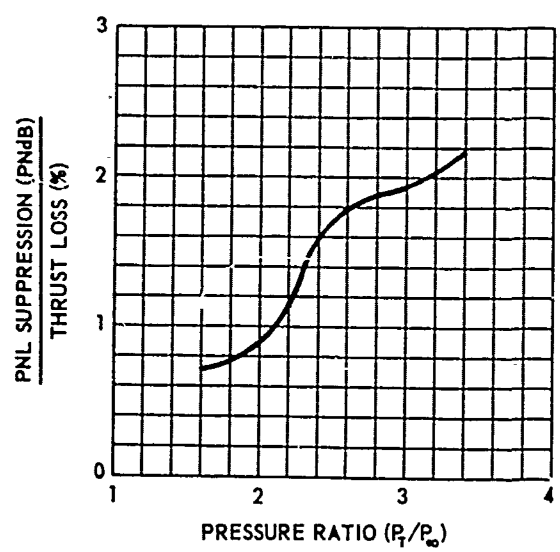
NO PICTURE AVAILABLE

Description:

The HM-AP-61-A nozzle is a 42-tube array surrounding a 24-spoke nozzle at the center of the array. There are 6 clusters of tubes with 7 tubes in each cluster. The center of each cluster is located at a 5.75 inch radius from the array center. The tube clusters are equally spaced at 60 degree arc intervals. Each tube has a 12-spoke nozzle termination.

Number of Elements: 42 tubes with
  12-spoke nozzle type ends and
  one 24-spoke nozzle
Area Ratio: 5.2
Tube Spacing (center-to-center):
  1.35 inches between tubes in
  each cluster
Flow Area: 28.2 square inches
Exit Cant Angle: 0 degrees
Length of Tubes: 7 inches
Tube Terminations:
  12 spokes with AR = 1.86
  75% spoke penetration
  0.92 inches outside diameter
  A_F = 0.357 square inches
  0 degrees flow cant angle
  77 degrees ventilation gutter
    cant angle
Center Nozzle:
  24 spokes with AR = 2.0 (HM-AP-60 nozzle)
  90% spoke penetration
  13.2 square inches flow area
  0 degree flow cant angle
  20 degrees ventilation gutter
    cant angle
Material: 321 CRES



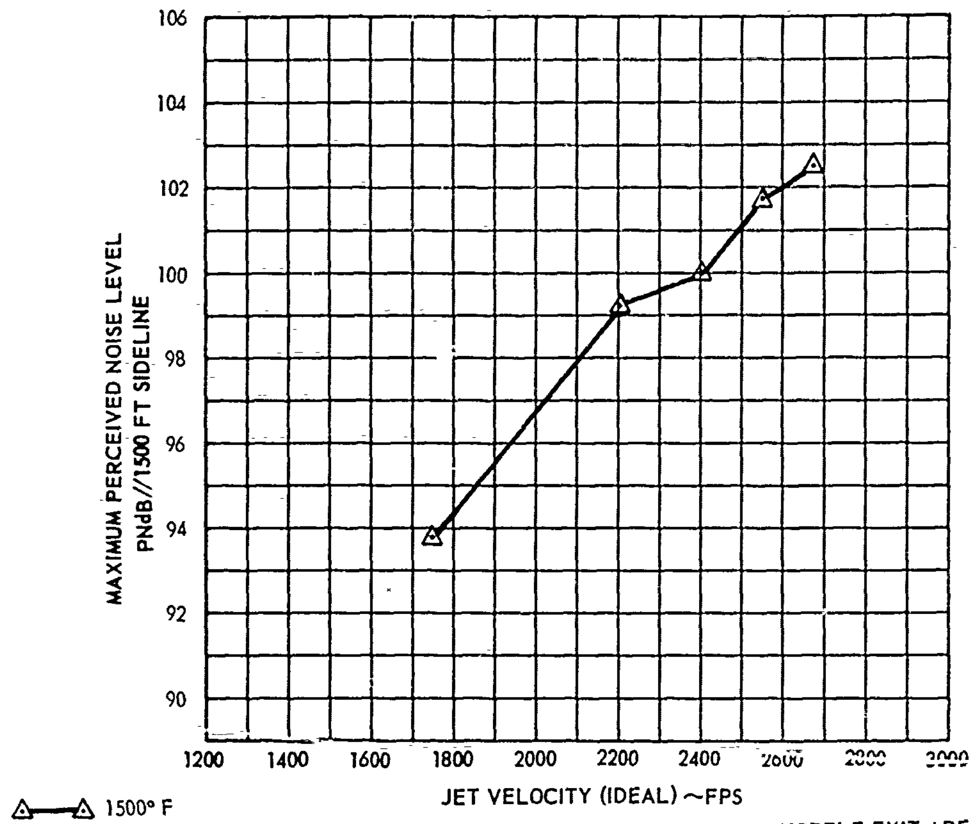


△—△ 1500° F

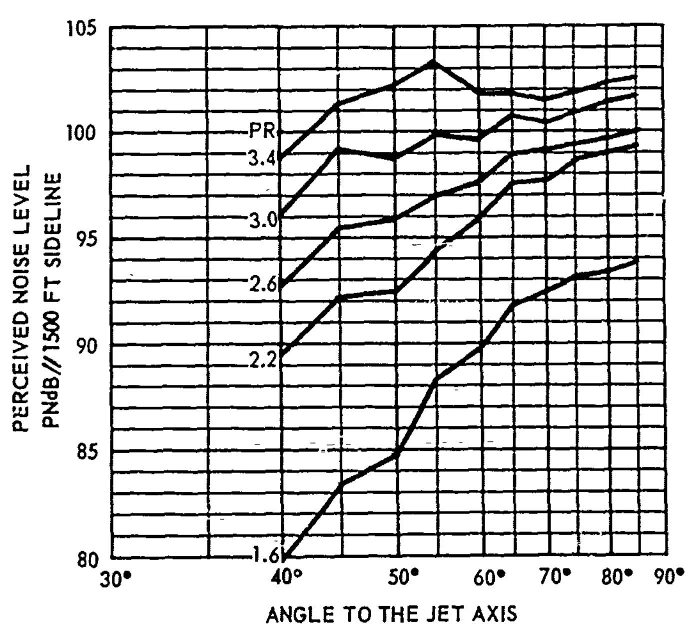
NOZZLE EXIT AREA (A_e): 12.6 FT^2

FREE FIELD VALUES

HM-AP-61-A NOZZLE
(42 TUBES, 6 CLUSTERS OF 7 TUBES EACH,
AND A 24 SPOKE NOZZLE IN THE CENTER)
AR 5.2, SCALE FACTOR: 8:1

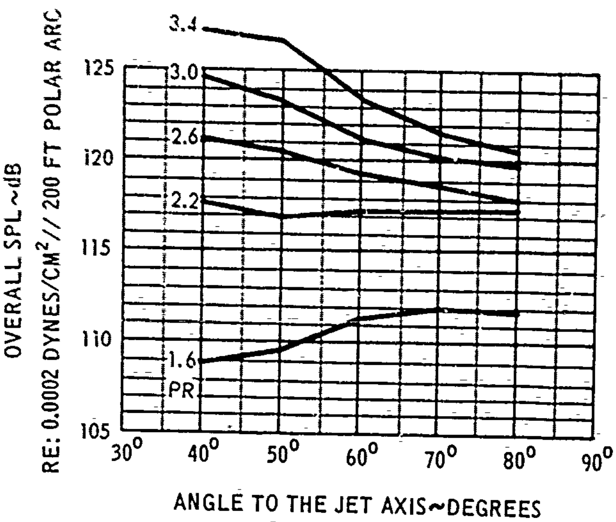


NOZZLE EXIT AREA (A_8): 12.6 FT^2

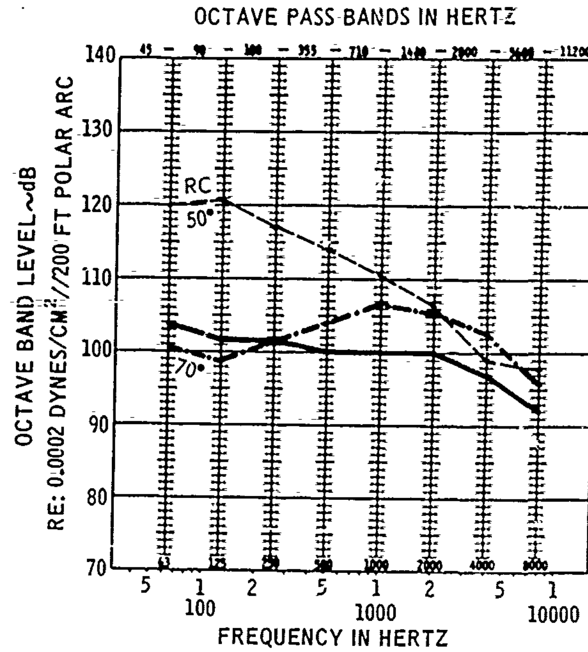


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT^2

FREE FIELD VALUES

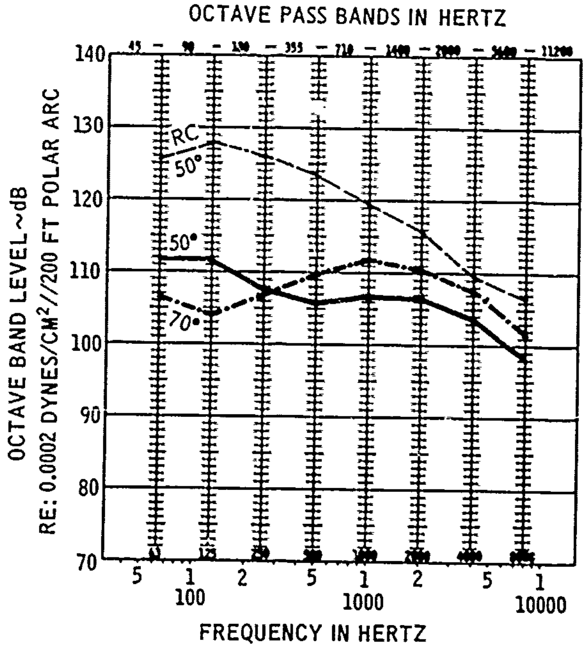


TOTAL TEMPERATURE (T$_8$) : 1500° F
NOZZLE EXIT AREA (A$_8$): 12.6 FT^2

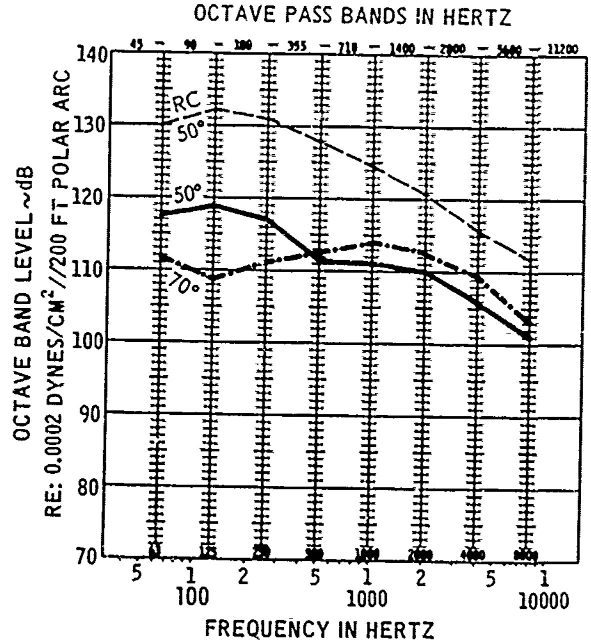


PRESSURE RATIO: 1.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1750 FPS
NOZZLE EXIT AREA (A$_8$): 12.6 FT^2

HM-AP-61-A NOZZLE
(42 TUBES, 6 CLUSTERS OF 7 TUBES EACH, AND A 24 SPOKE NOZZLE IN THE CENTER)
AR 5.2
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A$_8$): 12.6 FT^2



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A$_8$): 12.6 FT^2

FREE FIELD VALUES

HM-AP-61-A NOZZLE

(42 Tubes, 6 Clusters of 7 Tubes Each,
and a 24 Spoke Nozzle in the Center)

Remarks

The HM-AP-61-A Nozzle is essentially the HM-AP-58-A Nozzle plus the HM-AP-60 Nozzle. About 2 PNdB better suppression was realized with this nozzle relative to the 42 tube annulus with 24-spoke central element (HM-AP-64-A), however there are spectrum similarities. See Ref. D28. The spectrum indicates contribution from all elements in the array. The jet turbulence of the outer groupings of the 42 tubes does not appear to mask the low frequency noise generated by the larger 24-spoke jet in the center.

HM-AP-61-A NOZZLE

Test Facility: HNTF

Date:

T_{amb}:

R.H.:

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
11.1	1.6	1500°F	1750 fps	HM-AP-61-A
11.2	2.2	"	2202	"
11.3	2.6	"	2402	"
11.4	3.0	"	2555	"
11.5	3.4	"	2678	"
12.1	1.6	1500°F	1750 fps	6 Inch Round Convergent Nozzle
12.2	2.2	"	2202	"
12.3	2.6	"	2402	"
12.4	3.0	"	2555	"
12.5	3.4	"	2678	"

HM-AP-61-A NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
11-1 L40	108.8	105.3	101.5	98.3	98.2	97.8	96.0	94.2	93.9
11-1 L45	109.9	105.3	101.9	99.9	99.6	100.0	100.1	98.6	93.3
11-1 L50	109.5	103.6	101.7	101.4	99.9	100.1	100.1	97.0	92.0
11-1 L55	110.9	102.7	101.7	104.2	102.1	102.5	102.0	100.3	94.7
11-1 L60	111.4	102.0	102.2	104.4	103.2	103.4	103.2	100.5	95.3
11-1 L65	112.3	100.7	100.8	104.0	104.8	105.5	104.9	102.9	96.3
11-1 L70	112.0	100.2	98.8	101.3	103.9	106.8	105.4	102.4	95.5
11-1 L75	112.3	96.9	97.9	101.3	104.3	107.6	106.4	101.7	94.1
11-1 L80	111.9	97.1	96.8	99.2	103.0	106.8	106.4	103.4	96.5
11-1 L85	112.2	96.1	96.6	99.3	102.7	107.1	106.9	104.0	97.4
11-2 L40	117.7	114.7	112.4	106.1	103.8	104.7	102.2	100.1	95.7
11-2 L45	118.4	114.2	113.0	108.2	105.9	107.1	106.2	103.9	98.2
11-2 L50	116.9	111.4	111.4	108.2	105.8	106.5	106.3	103.1	97.9
11-2 L55	117.1	109.7	109.5	109.5	107.8	108.5	107.9	106.2	100.9
11-2 L60	117.2	107.9	108.5	109.1	108.7	109.8	109.2	106.8	102.1
11-2 L65	117.9	106.3	108.2	109.2	110.6	110.9	110.8	108.4	102.2
11-2 L70	117.3	106.3	[illegible]	106.5	109.5	111.7	110.5	107.7	101.2
11-2 L75	117.6	102.2	103.3	106.5	109.7	112.4	111.9	107.8	100.7
11-2 L80	117.4	102.1	102.0	104.2	108.0	111.8	112.1	109.7	103.2
11-2 L85	117.4	101.1	101.6	104.6	107.8	111.9	112.2	109.7	103.6
11-3 L40	121.2	118.1	116.1	110.6	105.8	106.7	104.5	102.3	99.2
11-3 L45	121.7	117.5	116.9	112.8	107.9	109.0	108.0	105.6	100.4
11-3 L50	120.5	114.9	115.6	112.7	109.6	109.1	108.5	105.0	99.9
11-3 L55	119.8	112.3	113.3	112.7	109.9	110.6	109.6	107.7	102.5
11-3 L60	119.4	110.4	111.8	111.7	110.9	111.5	110.6	107.7	102.8
11-3 L65	119.5	109.3	109.0	111.5	112.1	112.4	111.5	109.2	102.9
11-3 L70	118.8	109.0	106.9	109.4	111.3	112.8	111.2	108.4	102.1
11-3 L75	118.4	104.8	105.7	108.2	110.9	113.1	112.1	107.6	100.2
11-3 L80	118.0	104.6	104.2	106.2	109.3	112.5	112.1	109.6	103.3
11-3 L85	118.1	103.3	103.3	105.8	108.8	112.5	112.7	110.3	104.0
11-4 L40	124.6	121.5	119.7	114.5	108.7	109.3	107.0	104.0	101.3
11-4 L45	125.4	120.9	120.5	117.6	111.5	112.4	111.7	108.9	103.4
11-4 L50	123.4	117.3	118.7	116.9	111.3	110.9	109.8	105.7	100.9
11-4 L55	122.5	114.6	116.4	116.6	112.8	112.5	110.9	108.5	103.3
11-4 L60	121.3	112.3	114.4	114.3	113.0	113.0	111.7	108.8	104.1
11-4 L65	121.3	111.7	111.4	113.5	113.8	114.2	113.1	110.6	104.4
11-4 L70	120.2	111.4	108.8	110.9	112.5	113.9	112.4	109.5	103.1
11-4 L75	119.7	106.7	107.6	110.1	112.2	114.0	113.2	109.1	102.2
11-4 L80	119.8	106.8	106.3	107.9	110.8	114.0	113.8	111.7	105.5
11-4 L85	119.9	105.9	105.5	107.9	110.7	114.0	114.2	112.1	106.0
11-5 L40	127.2	124.0	122.4	117.1	111.4	112.0	110.1	106.3	103.8
11-5 L45	127.6	123.1	122.9	120.2	113.7	[illegible]	112.7	[illegible]	104.5
11-5 L50	126.6	120.3	121.9	120.8	114.7	113.3	111.9	107.3	102.8
11-5 L55	125.8	117.1	119.0	120.9	116.3	115.0	112.9	110.0	104.7
11-5 L60	123.6	114.7	117.3	117.1	115.2	114.6	112.8	109.4	104.7
11-5 L65	122.8	113.3	113.5	115.5	115.6	115.6	113.8	110.7	104.4
11-5 L70	121.6	113.4	111.2	113.3	114.0	115.1	112.9	109.5	103.2
11-5 L75	121.0	108.7	109.6	112.2	113.9	115.1	114.0	109.6	102.7
11-5 L80	120.6	108.6	108.3	109.8	112.4	114.8	114.1	111.9	105.6
11-5 L85	120.7	107.5	107.1	109.3	112.4	114.8	114.6	112.3	106.1

NOTE: THESE ARE FREE FIELD VALUES

HM-AP-61-A NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
12-1 L40	126.3	122.6	121.6	117.5	113.8	109.9	105.1	100.2	100.5
12-1 L45	126.7	122.9	122.1	116.1	114.5	111.0	106.6	100.4	100.6
12-1 L50	124.8	119.9	120.5	117.0	114.0	110.3	106.2	99.1	97.8
12-1 L55	123.9	117.7	118.8	117.5	114.9	111.9	107.1	101.8	98.1
12-1 L60	122.3	115.3	117.2	115.8	114.0	111.5	106.7	100.7	96.5
12-1 L65	121.1	113.7	114.7	114.9	114.0	110.9	107.0	101.9	95.2
12-1 L70	119.8	113.5	112.4	113.1	112.5	110.6	106.0	100.4	94.3
12-1 L75	118.9	109.5	111.5	113.0	112.5	110.4	106.3	99.1	92.3
12-1 L80	117.6	109.4	110.0	110.8	110.8	109.7	105.7	100.9	93.3
12-1 L85	117.0	108.3	108.7	110.5	110.6	109.2	105.9	100.7	93.1
12-2 L40	133.5	128.6	128.4	126.7	123.5	119.6	115.3	111.7	109.8
12-2 L45	134.4	129.1	129.2	127.8	124.7	120.9	117.3	112.5	109.6
12-2 L50	132.3	125.6	127.8	126.0	123.2	119.3	115.6	109.4	106.5
12-2 L55	131.5	123.2	126.5	125.9	123.2	120.2	115.7	111.0	106.8
12-2 L60	129.2	120.5	123.9	123.2	121.5	118.9	114.5	109.3	105.2
12-2 L65	128.0	118.9	120.8	122.1	121.8	118.9	115.0	110.4	103.7
12-2 L70	126.0	117.9	118.1	119.7	119.5	117.7	113.2	108.0	101.9
12-2 L75	125.3	114.3	117.2	119.4	119.5	117.7	113.4	106.8	99.9
12-2 L80	123.2	113.5	115.0	116.4	116.9	116.1	112.3	107.3	100.0
12-2 L85	123.2	112.6	113.9	116.4	117.2	116.0	113.2	108.3	101.0
12-3 L40	135.1	130.6	130.3	127.8	124.1	119.9	115.1	111.1	110.3
12-3 L45	136.3	131.3	131.4	129.5	126.0	121.9	117.7	112.8	111.0
12-3 L50	134.8	128.1	130.1	128.7	125.7	121.5	117.5	111.5	109.0
12-3 L55	134.0	125.7	128.9	128.7	125.6	122.3	117.8	113.3	109.7
12-3 L60	131.0	121.8	125.7	125.2	123.3	120.8	116.2	111.3	107.3
12-3 L65	129.5	120.4	122.3	123.6	123.3	120.6	115.5	111.9	105.7
12-3 L70	127.9	119.4	119.7	121.4	121.9	120.1	115.3	110.2	104.1
12-3 L75	127.2	115.7	118.5	120.9	121.5	120.1	116.1	109.8	103.1
12-3 L80	126.2	115.5	116.9	118.8	120.3	119.8	116.0	111.5	104.8
12-3 L85	126.0	114.5	115.4	118.6	120.8	119.4	116.0	111.6	104.6
12-4 L40	136.9	132.6	132.0	129.2	126.1	122.4	118.2	114.7	113.1
12-4 L45	138.3	133.4	133.3	131.2	127.9	124.4	120.7	116.2	113.6
12-4 L50	136.9	129.9	132.2	130.9	128.0	124.5	120.6	115.3	111.9
12-4 L55	136.2	126.9	130.6	130.9	128.5	125.7	121.7	117.9	113.8
12-4 L60	133.1	123.1	127.0	127.3	126.1	123.9	119.9	115.4	111.4
12-4 L65	131.9	121.9	124.0	125.8	125.8	123.6	120.0	116.1	110.2
12-4 L70	130.5	120.6	121.1	123.6	124.5	123.7	119.3	114.9	108.9
12-4 L75	130.2	117.3	120.0	123.3	124.9	123.7	120.1	114.5	107.8
12-4 L80	129.1	117.0	118.5	121.2	123.5	123.0	119.7	116.0	109.9
12-4 L85	129.1	116.0	117.0	121.2	124.2	122.7	119.8	116.1	109.8
12-5 L40	138.4	134.0	133.7	130.2	127.4	124.4	120.4	117.1	115.3
12-5 L45	139.8	134.8	135.0	132.5	[illegible]	[illegible]	[illegible]	118.3	115.7
12-5 L50	138.3	131.1	133.4	132.2	129.5	126.5	123.4	118.0	114.5
12-5 L55	136.1	128.0	131.8	132.6	131.0	128.5	124.8	121.4	117.2
12-5 L60	135.3	124.3	128.4	129.3	128.6	126.8	123.3	119.4	115.6
12-5 L65	135.4	122.5	124.8	126.9	127.6	125.7	122.4	118.6	112.7
12-5 L70	132.1	121.3	121.9	124.8	126.5	125.8	121.7	117.4	111.4
12-5 L75	132.0	118.1	121.2	124.6	125.9	125.6	122.4	117.0	110.5
12-5 L80	131.2	117.8	119.5	122.9	125.7	125.3	122.1	118.7	112.7
12-5 L85	131.4	117.1	117.7	123.4	126.3	125.2	122.7	119.3	113.1

NOTE: THESE ARE FREE FIELD VALUES

HM-AP-64-A NOZZLE
(42 TUBE ANNULUS, 2 ROWS OF TUBES, AND 24 SPOKE NOZZLE IN THE CENTER, AR 4.4)

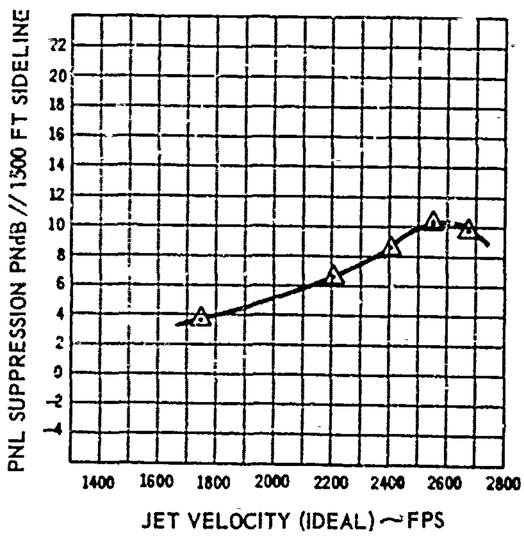
NO PICTURE AVAILABLE

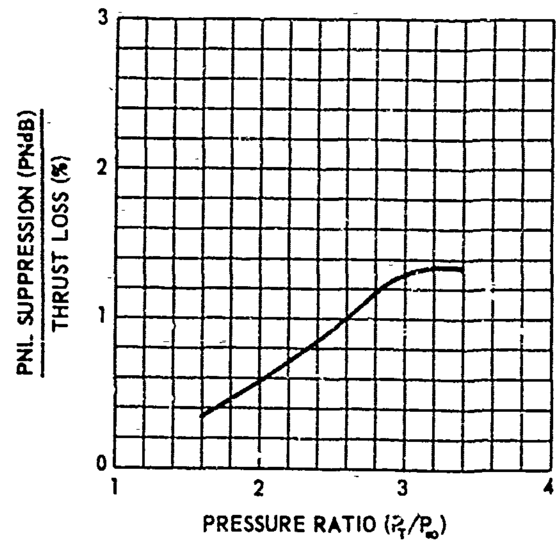
Description:
The HM-AP-64-A nozzle is a 42-tube annulus array with a 24-spoke, area ratio 2.0 nozzle in the center of the array. There are 21 tubes in the outer row and 21 tubes in the inner row of tubes. Each individual tube has a 12-spoke nozzle termination.

Number of Elements: 42 tubes with 12-spoke nozzle type ends and one 24-spoke nozzle
Area Ratio: 4.4
Tube Spacing (between inner and outer rows): 1.35 inches
Flow Area: 28.2 square inches
Exit Cant Angle: 0 degrees
Length of Tubes: 7 inches
Tube Terminations:
- 12 spokes with AR = 1.86
- 75% spoke penetration
- 0.92 inches outside diameter
- A_F = 0.357 square inches
- 0 degrees cant angle
- 77 degrees ventilation gutter cant angle

Center Nozzle:
- 24 spokes with AR = 2.0 (HM-AP-60 nozzle)
- 90% spoke penetration
- 13.2 square inches flow area
- 0 degrees exit cant angle
- 20 degrees ventilation gutter cant angle

Material: 321 CRES



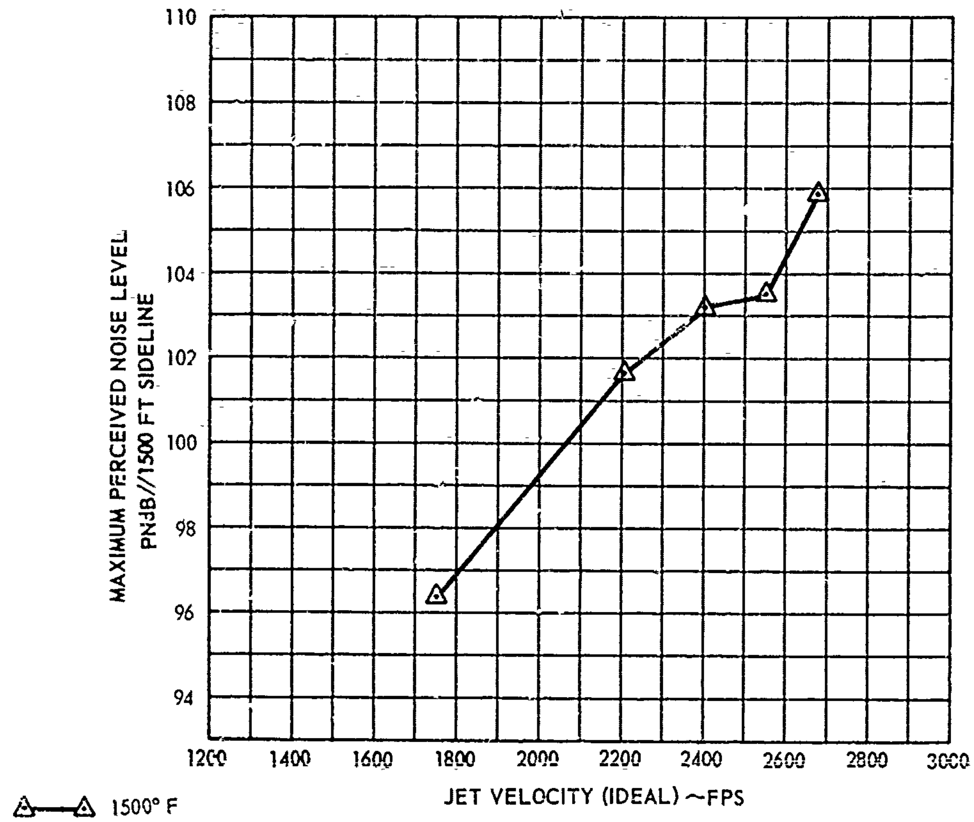


△—△ 1500° F

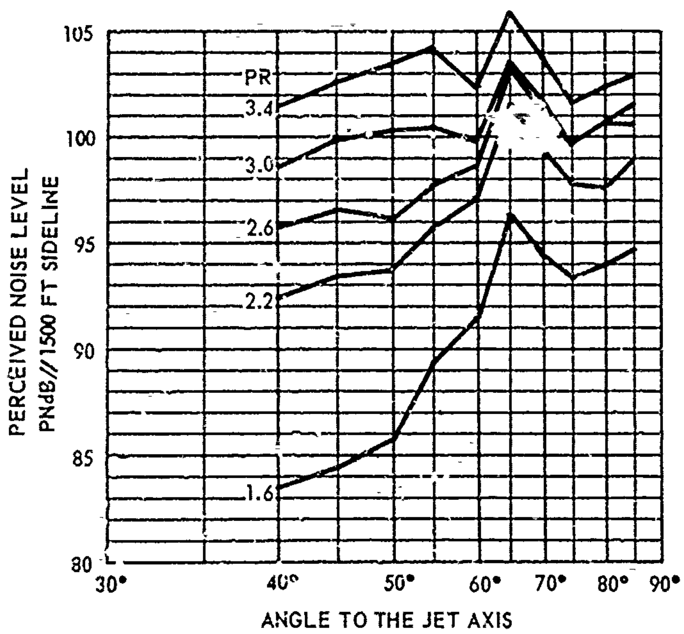
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

HM-AP-64-A NOZZLE
(42 TUBE ANNULUS, 2 ROWS OF TUBES,
AND 24 SPOKE NOZZLE IN THE CENTER)
AR 4.4, SCALE FACTOR: 8:1



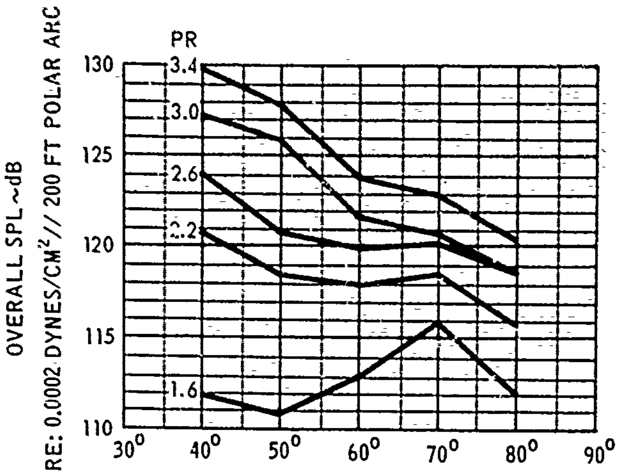
NOZZLE EXIT AREA (A_8): 12.6 FT^2



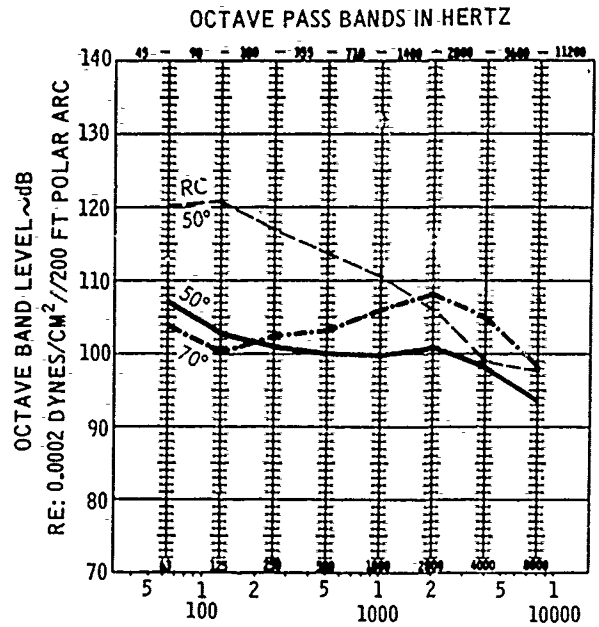
TOTAL TEMPERATURE (T_8): 1500° F

NOZZLE EXIT AREA (A_8): 12.6 FT^2

FREE FIELD VALUES

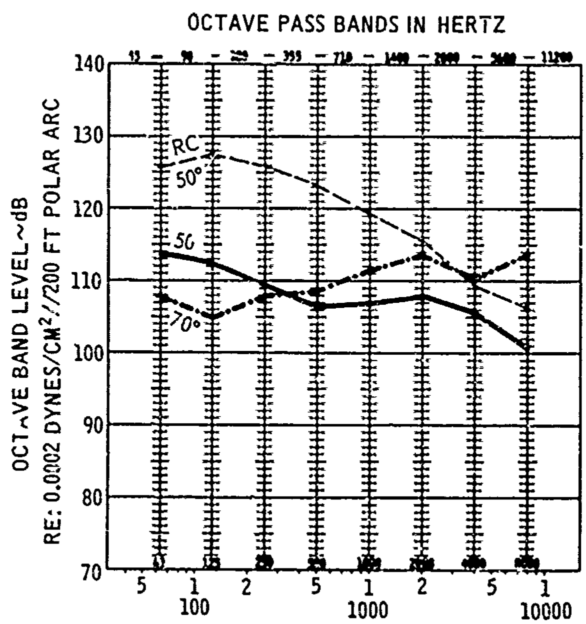


ANGLE TO THE JET AXIS~DEGREES
TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT²

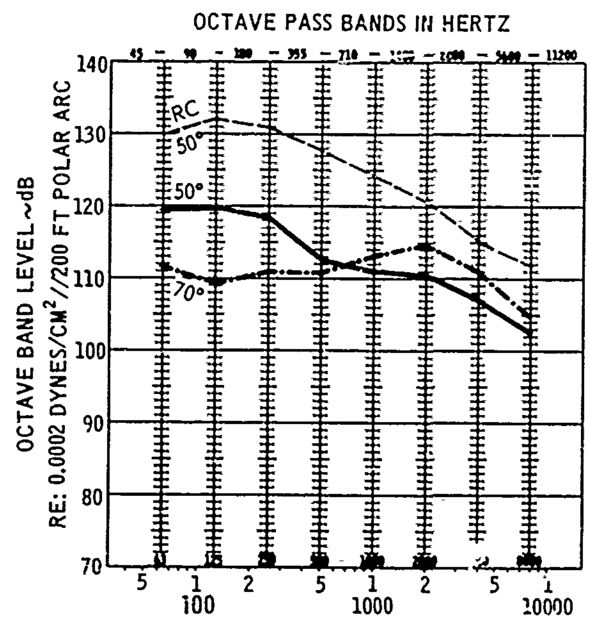


PRESSURE RATIO: 1.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1750 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²

HM-AP-64-A NOZZLE
(42 TUBE ANNULUS, 2 ROWS OF TUBES, AND 24 SPOKE NOZZLE IN THE CENTER)
AR 4.4
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

HM-AP-64-A NOZZLE

(42 Tube Annulus, 2 Rows of Tubes, and 24-Spoke Nozzle in the Center)

Remarks

The HM-AP-64-A Nozzle is essentially the HM-AP-59-A Nozzle plus the HM-AP-60 Nozzle. The noise spectrum shows definite contribution by all elements. The low frequencies are dominated by the relatively large 24-spoke jet in the center of the array. The high frequency portion of the spectrum is largely attributed to the 42 annulus jets. See Reference D28.

HM-AP-64-A NOZZLE

Test Facility: HNTF

Date:

T_{amb}:

R.H.:

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
24.1	1.6	1500°F	1750 fps	HM-AP-64-A
24.2	2.2	"	2202	"
24.3	2.6	"	2402	"
24.4	3.0	"	2555	"
24.5	3.4	"	2678	"
12.1	1.6	1500°F	1750 fps	6 Inch Round Convergent Noz.
12.2	2.2	"	2202	"
12.3	2.6	"	2402	"
12.4	3.0	"	2555	"
12.5	3.4	"	2678	"

HM-AP-64-A NOZZLE TEST DATA

OCTAVE BAND LEVEL—dB RE: 0.0002 DYNES/CM²// 25 FT.

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
24-1 L40	112.0	109.8	103.0	99.5	99.3	99.2	98.8	98.[illegible]	95.4
24-1 L45	111.3	106.0	103.2	100.2	99.7	99.7	100.7	98.[illegible]	93.1
24-1 L50	110.8	106.9	102.7	100.9	99.9	99.8	101.0	98.2	93.5
24-1 L55	113.0	109.4	102.8	103.5	101.9	102.2	103.4	101.4	96.2
24-1 L60	112.7	105.0	102.2	104.5	103.4	103.9	105.6	103.1	98.1
24-1 L65	116.0	103.2	101.0	104.2	104.3	107.5	111.8	109.7	100.9
24-1 L70	113.5	104.0	99.9	102.4	103.2	106.2	108.3	105.2	98.6
24-1 L75	112.0	101.6	98.4	100.8	103.0	105.5	106.8	102.3	96.1
24-1 L80	112.2	102.7	97.8	99.3	102.3	104.1	107.2	105.1	98.0
24-1 L85	112.8	103.2	97.9	99.2	102.7	105.6	107.5	105.5	99.2
24-2 L40	120.6	117.6	114.7	110.5	105.9	106.3	105.7	105.9	102.4
24-2 L45	119.8	115.9	114.4	110.5	106.4	106.5	107.0	105.2	99.5
24-2 L50	118.4	113.5	112.4	109.4	106.6	106.9	108.1	105.8	100.7
24-2 L55	119.0	114.2	110.3	109.8	107.9	108.7	109.9	108.3	102.8
24-2 L60	118.0	109.3	108.2	109.2	108.2	109.3	111.3	109.4	104.5
24-2 L65	121.3	107.9	106.6	109.2	109.4	112.5	117.2	115.2	106.6
24-2 L70	118.5	107.8	105.0	107.8	108.7	111.5	113.5	110.2	103.8
24-2 L75	116.4	104.9	103.2	105.9	107.4	110.1	111.2	106.6	100.3
24-2 L80	115.8	105.1	102.3	103.8	105.9	107.7	110.8	108.7	101.7
24-2 L85	117.0	105.5	102.0	104.0	106.8	109.6	112.0	109.9	103.6
24-3 L40	124.1	121.0	118.5	114.9	108.6	109.1	108.3	108.4	104.7
24-3 L45	123.1	119.0	117.9	115.0	108.9	108.9	109.0	106.5	101.2
24-3 L50	120.8	115.9	115.5	113.0	108.7	108.2	108.6	105.8	100.6
24-3 L55	121.1	116.4	113.3	112.8	110.3	110.6	111.0	109.2	103.8
24-3 L60	119.8	111.3	110.9	111.5	110.2	111.1	112.6	110.4	105.8
24-3 L65	122.8	110.0	109.1	111.5	111.1	113.9	118.5	116.4	107.8
24-3 L70	120.1	109.9	107.5	109.7	110.1	112.8	114.8	111.8	105.5
24-3 L75	118.1	106.7	105.5	108.1	109.0	111.5	112.8	108.3	102.3
24-3 L80	118.7	106.6	104.7	106.3	106.2	110.6	113.9	112.0	105.3
24-3 L85	118.5	106.9	104.1	106.3	108.8	111.3	113.3	111.4	105.1
24-4 L40	127.3	124.4	122.0	117.4	110.8	110.9	109.9	109.0	105.9
24-4 L45	126.6	122.5	121.7	119.3	112.1	111.2	110.9	107.9	103.2
24-4 L50	124.8	119.4	119.8	118.5	112.5	110.9	110.4	106.9	102.4
24-4 L55	123.5	118.7	116.7	116.6	113.0	112.0	111.4	108.6	103.3
24-4 L60	121.6	114.0	114.3	114.2	112.5	112.2	112.6	109.6	104.6
24-4 L65	123.1	112.2	111.5	113.0	112.5	114.5	118.2	115.6	106.9
24-4 L70	120.7	111.8	109.4	111.2	111.1	113.2	114.7	111.2	104.9
24-4 L75	118.5	108.3	107.3	109.4	110.0	111.9	112.4	107.3	101.1
24-4 L80	118.7	108.2	106.7	107.7	109.0	110.6	113.4	111.1	104.3
24-4 L85	119.4	108.6	106.0	107.6	109.5	112.1	114.0	112.1	106.1
24-5 L40	129.8	126.6	124.8	120.2	113.9	113.9	113.1	111.7	108.2
24-5 L45	129.1	124.5	124.4	12[illegible].1	115.3	114.2	114.0	110.7	105.7
24-5 L50	127.8	121.9	122.7	122.1	116.3	114.0	113.6	109.8	105.1
24-5 L55	126.8	120.7	119.9	121.0	117.1	115.7	115.1	112.3	107.0
24-5 L60	123.9	115.4	116.2	116.7	115.2	114.9	115.2	112.4	107.8
24-5 L65	125.5	114.1	113.9	115.5	115.1	117.1	120.6	118.1	109.8
24-5 L70	123.0	113.6	111.9	114.0	113.8	115.6	117.0	113.5	107.4
24-5 L75	120.4	110.2	109.7	111.8	112.1	113.6	114.0	108.7	102.7
24-5 L80	120.4	110.0	108.7	109.9	111.1	112.6	114.9	112.2	105.3
24-5 L85	120.9	110.1	107.9	109.8	112.0	113.8	115.2	113.1	106.9

NOTE: THESE ARE FREE FIELD VALUES

HM-AP-64-A NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
12-1 L40	126.3	122.6	121.6	117.5	113.8	109.9	105.1	100.2	100.5
12-1 L45	126.7	122.9	122.1	118.1	114.5	111.0	106.6	100.4	100.6
12-1 L50	124.8	119.9	120.5	117.0	114.0	110.3	103.2	99.1	97.8
12-1 L55	123.9	117.7	118.8	117.5	114.9	111.9	107.1	101.8	98.1
12-1 L60	122.3	115.3	117.2	115.8	114.0	111.5	106.7	100.7	96.5
12-1 L65	121.1	113.7	114.7	114.9	114.0	110.9	107.0	101.9	95.2
12-1 L70	119.8	113.5	112.4	113.1	112.5	110.6	103.0	100.4	94.3
12-1 L75	118.9	109.5	111.5	113.0	112.5	110.4	106.3	99.1	92.3
12-1 L80	117.6	109.4	110.0	110.8	110.8	109.7	105.7	100.9	93.3
12-1 L85	117.0	108.3	108.7	110.5	110.6	109.2	105.9	100.7	93.1
12-2 L40	133.5	128.6	128.4	126.7	123.5	119.6	115.3	111.7	109.8
12-2 L45	134.4	129.1	129.2	127.8	124.7	120.9	117.3	112.5	109.8
12-2 L50	132.3	125.6	127.8	126.0	123.2	119.3	115.6	109.4	106.5
12-2 L55	131.5	123.2	126.5	125.9	123.2	120.2	115.7	111.0	106.8
12-2 L60	129.2	120.5	123.9	123.2	121.5	118.9	114.5	109.3	105.2
12-2 L65	128.0	118.9	120.8	122.1	121.8	118.9	115.0	110.4	103.7
12-2 L70	126.0	117.9	[illegible]	115.7	[illegible]	117.7	113.2	[illegible]	101.9
12-2 L75	125.3	114.3	117.2	119.4	119.5	117.7	113.4	106.8	99.9
12-2 L80	123.2	113.5	115.0	116.4	116.9	116.1	112.3	107.3	100.0
12-2 L85	123.2	112.6	113.9	116.4	117.2	116.0	113.2	108.3	101,0
12-3 L40	135.1	130.6	130.3	127.8	124.1	119.9	115.1	111.1	110.3
12-3 L45	136,3	131.3	131.4	129.5	126.0	121.9	117,7	112.8	111.0
12-3 L50	134.8	128.1	130.1	128.7	125.7	121.5	117.5	111.5	109.0
12-3 L55	134.0	125.7	128.9	128.7	125.6	122.3	117.8	113.3	109.7
18-3 L60	131.0	121.8	125.7	125.2	123.3	120.8	118.2	111.3	107.3
12-3 L65	129.5	120.4	122.3	123.6	123.3	120.6	118.5	111.9	105.7
12-3 L70	127.9	119.4	119.7	121.4	121.8	120.1	115.3	110.2	104.1
12-3 L75	127.2	115.7	118.5	120.9	121.5	120.1	116.1	109.8	103.1
12-3 L80	126.2	115.5	116.9	118.8	120.3	119.8	116.0	111.5	104.8
12-3 L85	126.0	114.5	115.4	118.6	120.8	119.4	116,0	111.6	104.6
12-4 L40	136.9	132.6	132.0	129.2	126.1	122.4	118.2	114.7	113.1
12-4 L45	138.3	133.4	133.3	131.2	127.9	124.4	120.7	116.2	113.6
12-4 L50	136.9	129.9	132.2	130.9	128.0	124.5	120.8	115.3	111.9
12-4 L55	136.2	126.9	130.6	130.9	128.5	125.7	121.7	117.9	113.8
12-4 L60	133.1	123.1	127.0	127.3	126.1	123.9	119.9	115.4	111.4
12-4 L65	131.9	121.9	124.0	125.8	125.8	123.6	120.0	116.1	110.2
12-4 L70	130.5	120.6	121.1	123.6	124.5	123.7	119.3	114.9	108.9
12-4 L75	130.2	117.3	120.0	123.3	124.9	123.7	120.1	114.5	107.8
12-4 L80	129.1	117.0	116.5	121.2	123.5	123.0	119.7	116.0	109.9
12-4 L85	129.1	116.0	117.0	121.2	124.2	122.7	119.8	116.1	109.8
12-5 L40	138.4	134.0	133.7	130.2	127.4	124.4	120.4	117.1	115.3
12-5 L45	139.8	134.8	135.0	132.5	[illegible]	[illegible]	[illegible]	[illegible]	115.7
12-5 L50	138.3	131.1	133.4	132.2	129.5	126.5	123.4	118.0	114.5
12-5 L55	136.1	128.0	131.8	132.6	131.0	128.5	124.8	121.4	117.2
12-5 L60	135.3	124.3	128.4	129.3	128.6	126.8	123.3	119.4	115.6
12-5 L65	133.4	122.5	124.8	126.9	127.6	125.7	122.4	118.6	112.7
12-5 L70	132.1	121.3	121.9	124.8	126.5	125.8	121.7	117.4	111.4
12-5 L75	132.0	118.1	121.2	124.6	126.9	125.6	122.4	117.0	110.5
12-5 L80	131.2	117.8	119.5	122.9	125.7	125.3	122.1	118.7	112.7
12-5 L85	131.4	117.1	117.7	123.4	126.3	125.2	122.7	119.3	113.1

NOTE: THESE ARE FREE FIELD VALUES

HM-AP-65-A NOZZLE
(42 TUBE ANNULUS, 2 ROWS OF TUBES AND RC NOZZLE IN THE CENTER, AR 4)

PICTURE NOT AVAILABLE

Description:

The HM-AP-65-A nozzle is a 42-tube annulus array with a round convergent nozzle in the center of the array. There are 21 tubes in the outer row and 21 tubes in the inner row of tubes. Each individual tube has a 12-spoke nozzle termination. The round convergent nozzle in the center of the array has a diameter of 4.1 inches.

Number of Elements: 42 Tubes with 12 spoke nozzle type ends and one round convergent nozzle.

Area Ratio: 4.4

Tube Spacing (between inner and outer rows): 1.35 Inches

Flow Area: 28.2 Square Inches

Exit Cant Angle: 0 Degrees

Length of Tubes: 7 Inches

Tube Terminations: 12 Spokes with AR = 1.86

75% Spoke Penetration

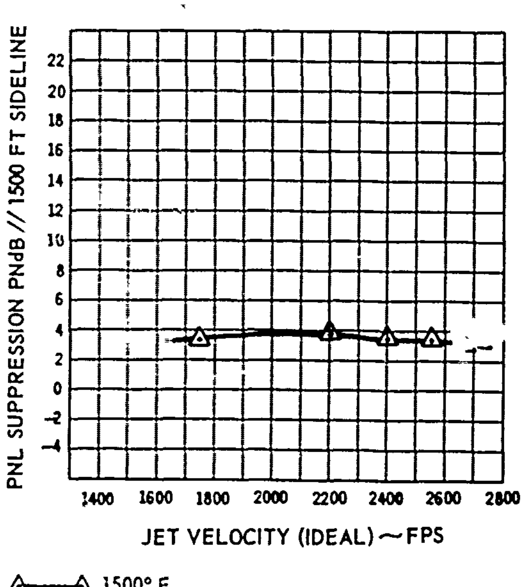
0.92 Inches Outside Diameter

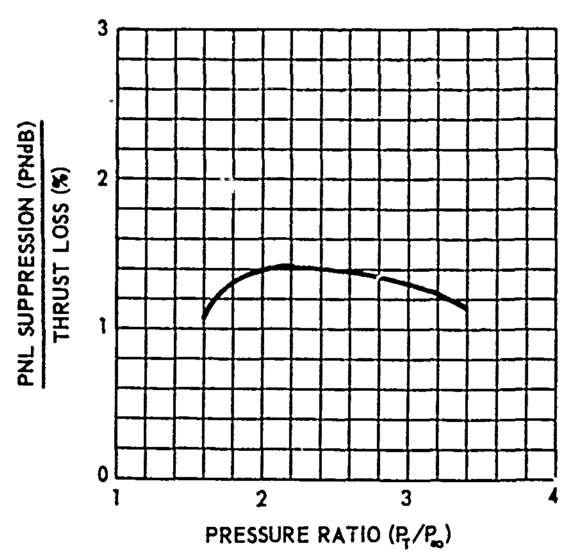
A_F = 0.357 Square Inches

0 Degrees Cant Angle

77 Degrees Ventilation Gutter Cant Angle

Material: 321 CRES

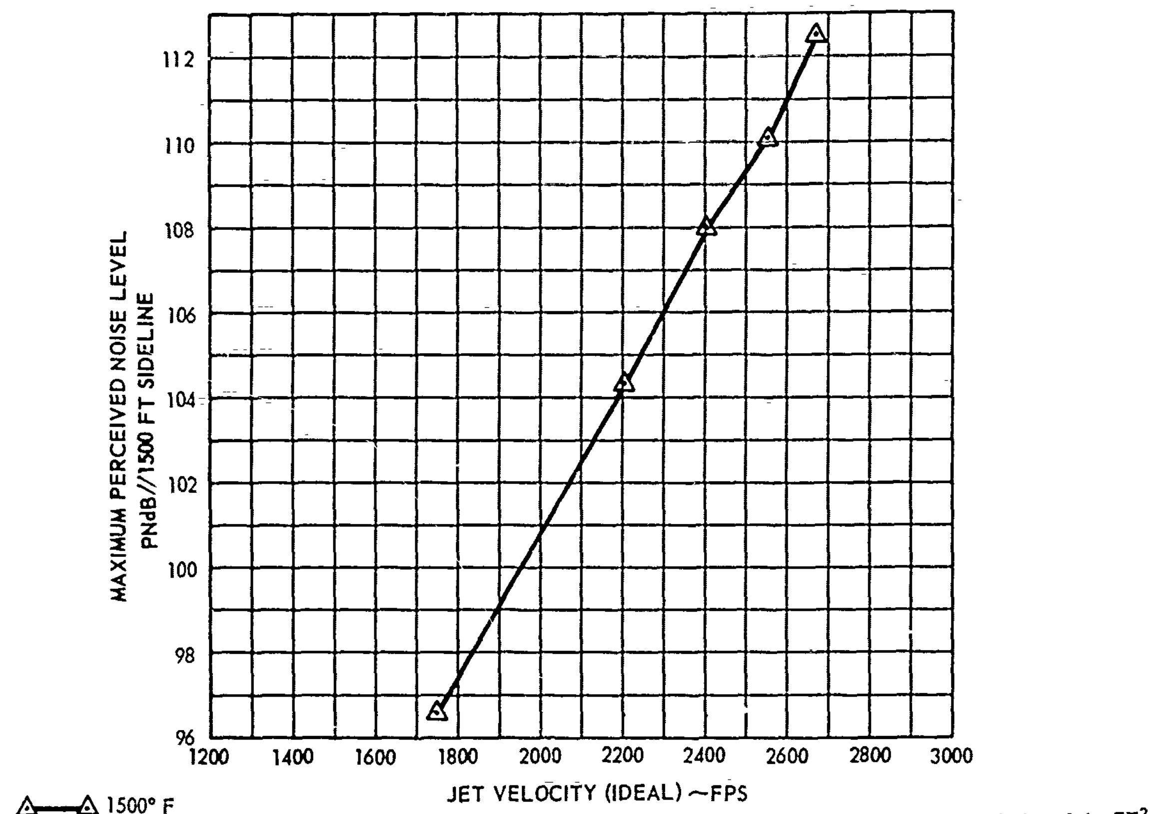




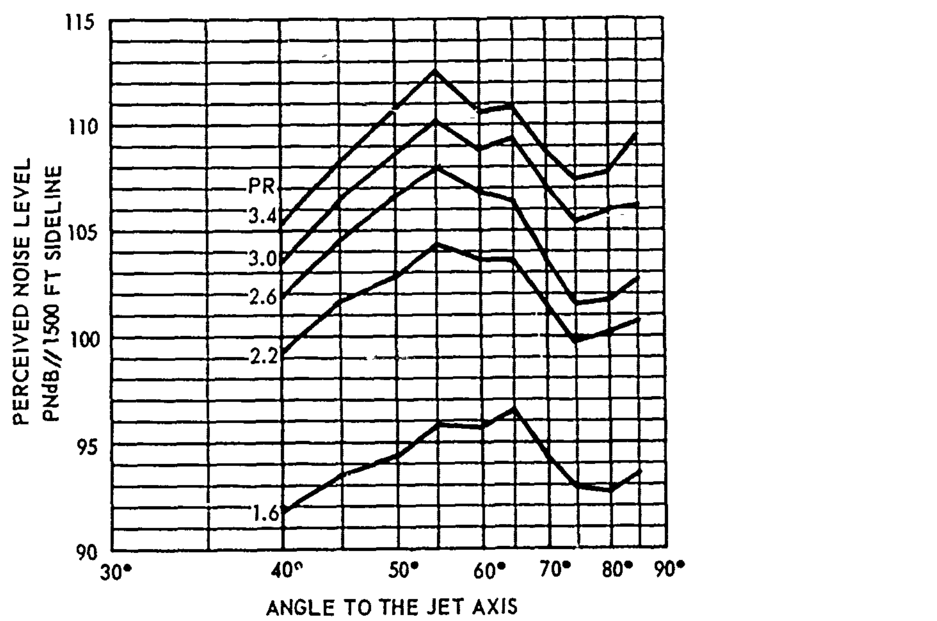
NOZZLE EXIT AREA (A_8): 12.6 FT^2

FREE FIELD VALUES

HM-AP-65-A NOZZLE
(42 TUBE ANNULUS, 2 ROWS OF TUBES,
AND RC NOZZLE IN THE CENTER)
AR 4.4, SCALE FACTOR: 8:1



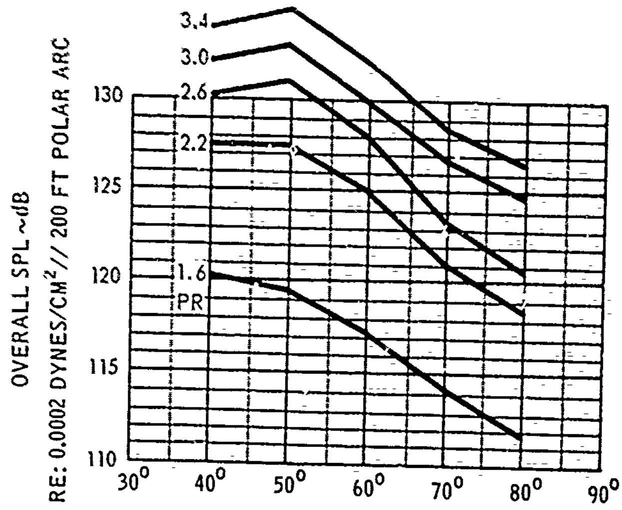
NOZZLE EXIT AREA (A_8): 12.6 FT^2



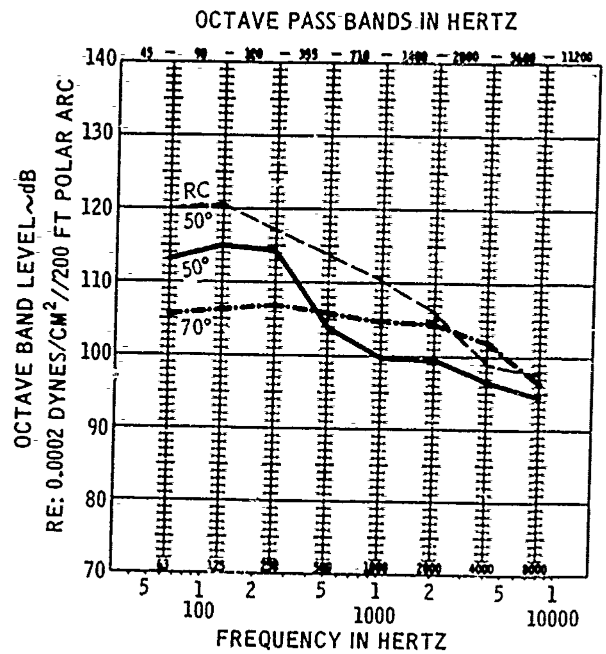
TOTAL TEMPERATURE (T_8): 1500° F

NOZZLE EXIT AREA (A_8): 12.6 FT^2

FREE FIELD VALUES

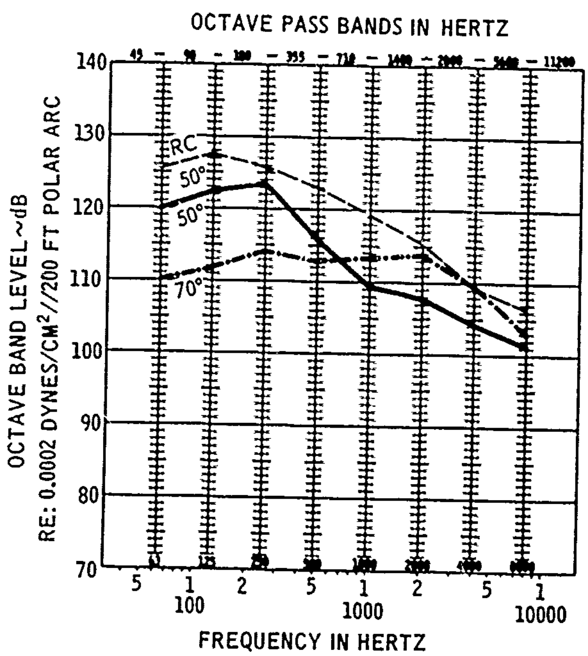


ANGLE TO THE JET AXIS~DEGREES
TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT²

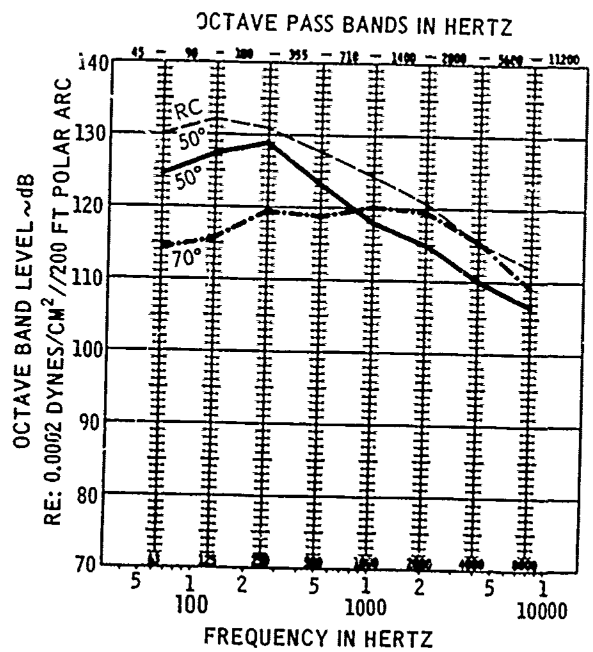


PRESSURE RATIO: 1.6
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1750 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²

HM-AP-65-A NOZZLE
(42 TUBE ANNULUS, 2 ROWS OF TUBES, AND RC NOZZLE IN THE CENTER)
AR 4.4
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

HM-AP-65-A NOZZLE

(42 Tube Annulus, 2 Rows of Tubes, and RC Nozzle in the Center)

Remarks

The HM-AP-65-A Nozzle is essentially the HM-AP-59-A Nozzle configuration with a 4.1 inch diameter round convergent nozzle added. The noise characteristics of the HM-AP-65-A Nozzle was dominated by the 4.1 inch diameter round convergent nozzle in the center of the array. See Ref D28. The turbulent jets from the 42 tubes surrounding the relatively larger central jet did not effectively shield the noise generated by the central jet. The spectrum measured on the HM-AP-65-A indicated that the superposition theorem can not be used with a combination type nozzle.

HM-AP-65-A NOZZLE

Test Facility: HNTF

Date:

T_{amb}:

R.H.:

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
23.1	1.6	1500°F	1750 fps	HM-AP-65-A
23.2	2.2	"	2202	"
23.3	2.6	"	2402	"
23.4	3.0	"	2555	"
23.5	3.4	"	2678	"
12.1	1.6	1500°F	1750 fps	6 Inch Round Convergent Noz.
12.2	2.2	"	2202	"
12.3	2.6	"	2402	"
12.4	3.0	"	2555	"
12.5	3.4	"	2678	"

HM-AP-65-A NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
23-1 L40	120.2	116.0	114.7	114.9	101.4	96.0	96.8	97.5	96.5
23-1 L45	120.2	115.4	115.3	115.2	102.3	98.6	98.4	96.5	95.2
23-1 L50	119.4	113.2	115.1	114.6	103.7	99.8	99.6	96.8	94.5
23-1 L55	119.2	113.2	113.7	114.8	105.9	102.8	101.8	99.1	95.6
23-1 L60	117.3	108.8	111.7	112.3	107.4	106.0	104.9	101.5	97.1
23-1 L65	116.8	106.8	108.6	109.7	107.3	107.7	109.7	107.0	98.6
23-1 L70	114.2	105.6	106.5	107.1	105.9	105.7	105.6	102.1	96.3
23-1 L75	112.5	103.5	104.1	105.4	105.1	104.7	103.8	99.2	93.6
23-1 L80	111.7	103.9	102.7	103.6	103.5	102.9	103.6	101.1	94.7
23-1 L85	112.2	104.2	102.1	103.9	103.8	104.2	104.2	102.4	96.7
23-2 L40	127.5	123.1	122.1	122.1	111.9	106.4	104.7	104.1	103.0
23-2 L45	128.1	122.4	122.8	123.7	114.1	107.8	106.8	103.8	101.9
23-2 L50	127.4	119.8	122.6	123.5	115.4	108.9	107.8	104.0	101.2
23-2 L55	127.1	119.0	120.9	123.8	116.3	111.2	110.1	106.6	102.2
23-2 L60	124.9	113.9	118.2	121.3	115.7	112.7	112.4	108.8	104.4
23-2 L65	123.8	111.3	114.2	117.3	114.6	115.0	117.4	114.2	105.5
23-2 L70	121.0	110.0	111.8	114.0	112.7	113.3	113.8	109.6	103.1
23-2 L75	118.9	107.3	109.2	111.7	111.3	112.1	111.6	106.4	100.3
23-2 L80	118.5	107.4	108.3	110.0	110.1	111.0	112.1	109.1	102.2
23-2 L85	119.0	107.3	107.4	110.1	110.7	112.1	112.4	110.0	103.7
23-3 L40	130.2	126.1	124.7	124.5	116.0	110.2	107.2	104.9	104.4
23-3 L45	130.9	125.4	125.5	126.3	118.5	112.0	109.1	104.4	103.9
23-3 L50	131.1	123.0	125.8	127.3	120.7	114.2	111.0	105.4	103.2
23-3 L55	130.7	121.4	124.0	127.6	121.1	116.1	113.0	108.4	104.1
23-3 L60	128.1	116.5	120.5	124.9	119.8	116.5	114.6	110.1	105.5
23-3 L65	126.7	114.0	116.8	121.3	118.2	117.9	119.4	115.5	106.5
23-3 L70	123.3	112.4	114.0	116.9	115.6	115.9	115.4	110.8	104.3
23-3 L75	121.1	109.3	111.3	114.8	114.0	114.5	112.6	106.1	99.6
23-3 L80	120.5	109.6	110.3	113.0	113.1	113.9	113.0	108.6	101.0
23-3 L85	121.4	109.3	109.3	112.8	114.6	115.5	113.9	110.6	104.0
23-4 L40	131.9	128.0	126.6	125.3	118.3	113.7	111.3	109.2	107.3
23-4 L45	132.5	127.1	127.3	127.5	120.4	115.3	113.2	109.0	106.5
23-4 L50	132.9	124.5	127.5	128.9	123.2	117.7	115.0	109.9	106.6
23-4 L55	132.5	122.4	125.6	129.2	124.3	119.7	116.9	112.5	107.9
23-4 L60	130.1	118.0	122.4	126.4	122.4	119.3	117.8	113.7	109.3
23-4 L65	129.3	115.7	118.5	122.8	120.8	121.1	123.0	119.6	111.3
23-4 L70	126.7	114.1	115.6	119.5	118.9	120.2	119.6	115.3	109.3
23-4 L75	124.9	110.9	113.1	117.4	118.0	119.4	117.1	111.2	105.5
23-4 L80	124.7	111.0	112.0	115.5	117.9	118.7	117.8	114.3	107.9
23-4 L85	125.0	110.4	110.7	114.8	119.8	118.9	117.4	114.1	107.9
23-5 L40	133.8	130.4	128.7	125.8	120.0	116.4	114.1	111.9	110.0
23-5 L45	134.7	129.7	129.8	128.8	122.7	118.3	116.3	111.8	109.1
23-5 L50	134.9	127.0	129.8	130.4	125.4	120.6	118.1	113.0	109.5
23-5 L55	135.1	124.5	128.1	131.3	127.5	123.3	120.3	115.8	111.3
23-5 L60	131.9	119.7	124.1	127.8	124.9	121.6	119.5	115.4	111.1
23-5 L65	130.9	117.2	119.8	124.3	122.9	123.0	124.3	120.8	112.4
23-5 L70	128.5	115.9	117.3	121.3	121.0	122.5	121.0	116.6	110.5
23-5 L75	127.0	112.4	114.8	119.2	120.9	121.8	118.8	112.7	106.9
23-5 L80	126.6	112.6	113.5	117.4	121.0	120.4	119.3	115.4	109.1
23-5 L85	128.0	112.0	112.2	117.2	123.8	121.4	120.1	116.8	111.0

NOTE: THESE ARE FREE FIELD VALUES

HM-AP-65-A NOZZLE TEST DATA

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
12-1 L40	126.3	122.6	121.6	117.5	113.8	109.9	105.1	100.2	100.5
12-1 L45	126.7	122.9	122.1	118.1	114.5	111.0	106.6	100.4	100.6
12-1 L50	124.8	119.9	120.5	117.0	114.0	110.3	106.2	99.1	97.8
12-1 L55	123.9	117.7	118.8	117.5	114.9	111.9	107.1	101.8	98.1
12-1 L60	122.3	115.3	117.2	115.8	114.0	111.5	106.7	100.7	96.5
12-1 L65	121.1	113.7	114.7	114.9	114.0	110.9	107.0	101.9	95.2
12-1 L70	119.6	113.5	112.4	113.1	112.5	110.6	106.0	100.4	94.3
12-1 L75	118.9	109.5	111.5	113.0	112.5	110.4	106.3	99.1	92.3
12-1 L80	117.6	109.4	110.0	110.6	110.8	109.7	105.7	100.9	93.3
12-1 L85	117.0	108.3	108.7	110.5	110.6	109.2	105.9	100.7	93.1
12-2 L40	133.5	128.6	128.4	126.7	123.5	119.6	115.3	111.7	109.8
12-2 L45	134.4	129.1	129.2	127.8	124.7	120.9	117.3	112.5	109.8
12-2 L50	132.3	125.6	127.8	126.0	123.2	119.3	115.6	109.4	106.5
12-2 L55	131.5	123.2	126.5	125.9	123.2	120.2	115.7	111.0	106.8
12-2 L60	129.2	120.5	123.9	123.2	121.5	118.9	114.5	109.3	105.2
12-2 L65	128.0	118.9	120.8	122.1	121.8	118.9	115.0	110.4	103.7
12-2 L70	126.0	117.9	118.1	119.7	119.5	117.7	113.2	108.0	101.9
12-2 L75	125.3	114.3	117.2	119.4	119.5	117.7	113.4	106.8	99.9
12-2 L80	123.2	113.5	115.0	116.4	116.9	116.1	112.3	107.3	100.0
12-2 L85	123.2	112.6	113.9	116.4	117.2	116.0	113.2	108.3	101.0
12-3 L40	135.1	130.6	130.3	127.8	124.1	119.9	115.1	111.1	110.3
12-3 L45	136.3	131.3	131.4	129.5	126.0	121.9	117.7	112.8	111.0
12-3 L50	134.8	128.1	130.1	128.7	125.7	121.5	117.5	111.5	109.0
12-3 L55	134.0	125.7	128.9	128.7	125.6	122.3	117.8	113.3	109.7
12-3 L60	131.0	121.8	125.7	125.2	123.3	120.8	116.2	111.3	107.3
12-3 L65	129.5	120.4	122.3	123.6	123.3	120.6	116.5	111.9	105.7
12-3 L70	127.9	119.4	119.7	121.4	121.6	120.1	115.3	110.2	104.1
12-3 L75	127.2	115.7	118.5	120.9	121.5	120.1	116.1	109.8	103.1
12-3 L80	126.2	115.5	116.9	118.8	120.3	119.8	116.0	111.5	104.8
12-3 L85	126.0	114.5	115.4	118.6	120.8	119.4	116.0	111.6	104.6
12-4 L40	136.9	132.6	132.0	129.2	126.1	122.4	118.2	114.7	113.1
12-4 L45	138.3	133.4	133.3	131.2	127.9	124.4	120.7	116.2	113.6
12-4 L50	136.9	129.9	132.2	130.9	128.0	124.5	120.8	115.3	111.9
12-4 L55	136.2	126.9	130.6	130.9	128.5	125.7	121.7	117.9	113.8
12-4 L60	133.1	123.1	127.0	127.3	126.1	123.9	119.9	115.4	111.4
12-4 L65	131.9	121.9	124.0	125.8	125.8	123.6	120.0	116.1	110.2
12-4 L70	130.5	120.6	121.1	123.6	124.5	123.7	119.3	114.9	108.9
12-4 L75	130.2	117.3	120.0	123.3	124.9	123.7	120.1	114.5	107.8
12-4 L80	129.1	117.0	118.5	121.2	123.5	123.0	119.7	116.0	109.9
12-4 L85	129.1	116.0	117.0	121.2	124.2	122.7	119.8	116.1	109.8
12-5 L40	138.4	134.0	133.7	130.2	127.4	124.4	120.4	117.1	115.3
12-5 L45	139.8	134.8	135.0	132.5	129.4	126.3	122.8	118.6	115.7
12-5 L50	138.3	131.1	133.4	132.2	129.5	126.5	123.4	118.0	114.5
12-5 L55	138.1	128.0	131.8	132.6	131.0	128.5	124.8	121.4	117.2
12-5 L60	135.3	124.3	128.4	129.3	128.6	126.8	123.3	119.4	115.6
12-5 L65	133.4	122.5	124.8	126.9	127.6	125.7	122.4	118.6	112.7
12-5 L70	132.1	121.3	121.9	124.6	126.5	125.8	121.7	117.4	111.4
12-5 L75	132.0	118.1	121.2	124.6	126.9	125.6	122.4	117.0	110.5
12-5 L80	131.2	117.8	119.5	122.9	125.7	125.3	122.1	118.7	112.7
12-5 L85	131.4	117.1	117.7	123.4	126.3	125.2	122.7	119.3	113.1

NOTE: THESE ARE FREE FIELD VALUES

HM-AP-78 NOZZLE

16 SPOKES AND 208 TUBES, AR 3.1

Description:

Number of Elements: 16 spokes and 16 clusters of tubes

Area Ratio: 3.1

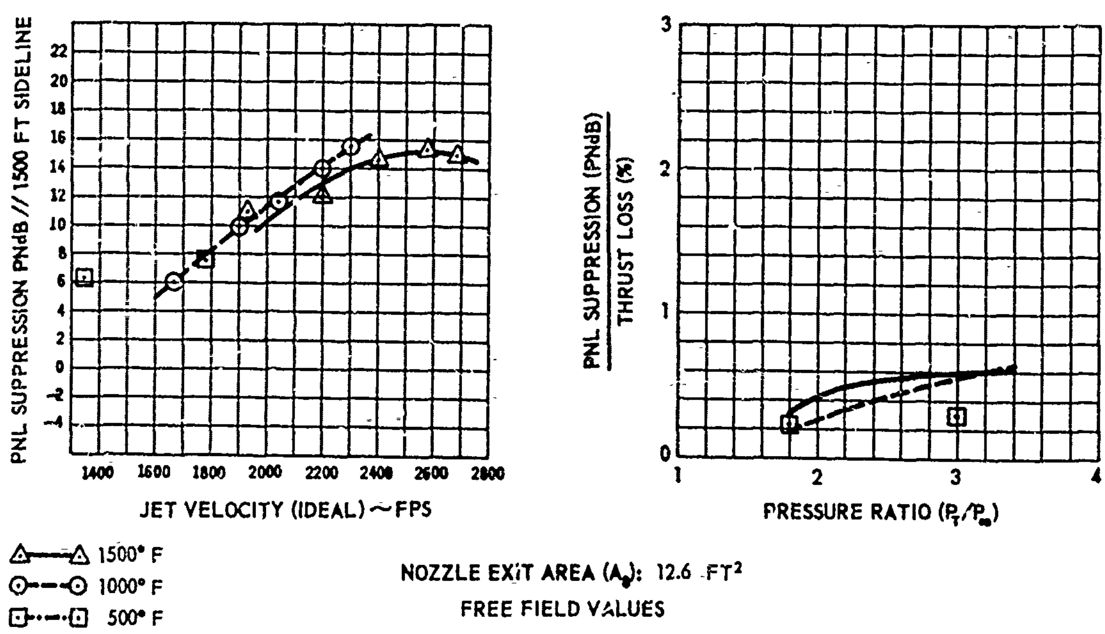
Spoke Penetration: 8 spokes at 68.5%, 4 spokes at 92.5%, and 4 spokes at 97.5%

Tube Arrangements: 8 clusters of tubes (15 tubes each); 8 clusters of tubes (11 tubes each)

Flow Area: 28 square inches

Exit Cant Angle: 0 degrees

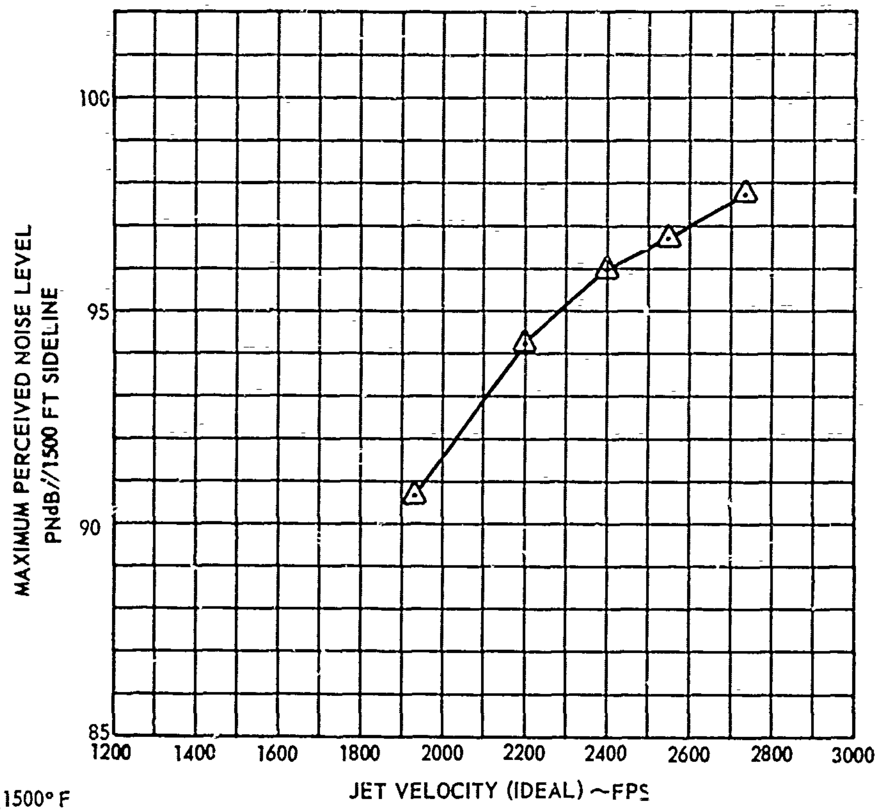
Material: 321 CRES



NOZZLE EXIT AREA (A_j): 12.6 FT^2

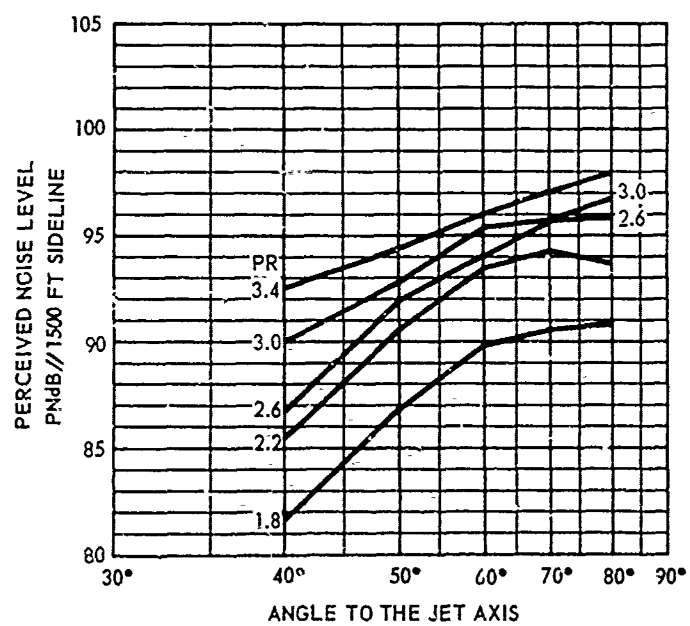
FREE FIELD VALUES

HM-AP-78 NOZZLE
(16 SPCKES AND 16 CLUSTERS OF TUBES)
AR 3.1
SCALE FACTOR: 8:1



NOZZLE EXIT AREA (A_8): 12.6 FT²

△—△ 1500° F
⊙---⊙ 1000° F
⊡-·-⊡ 500° F



TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

HM-AP-78 NOZZLE

(16 Spokes and 16 Clusters of Tubes)

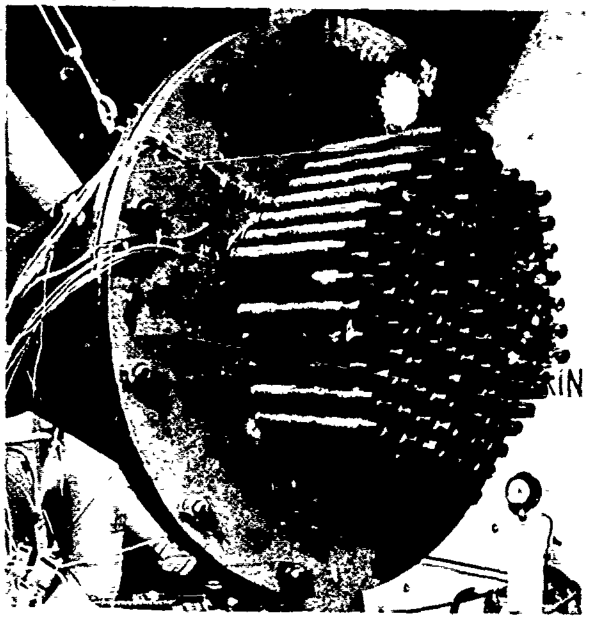
Remarks:

This nozzle is a 1/8th scale representation of a GE4 engine design concept (NSC-30). Although a peak sideline suppression value of 15.5 PNdB was attained, the static thrust loss was excessive, e.g., 25% thrust loss at PR = 3.4.

Original measured data has been lost. See Reference D29 for information concerning spectrum levels.

HM-AP-85-1 NOZZLE

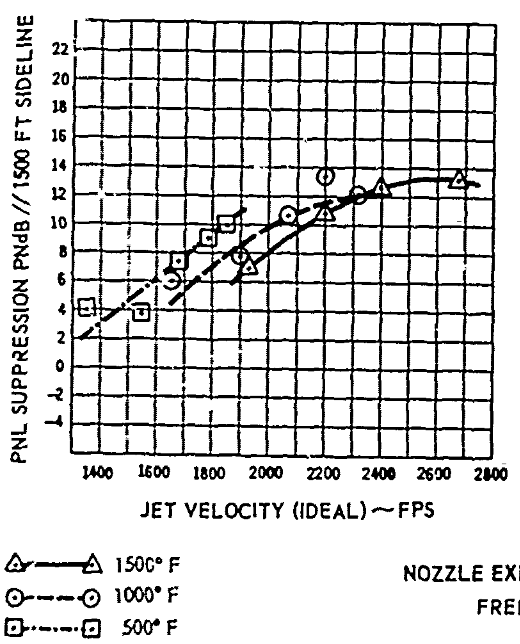
126 TUBE HEXAGONAL ARRAY, AR 3.33

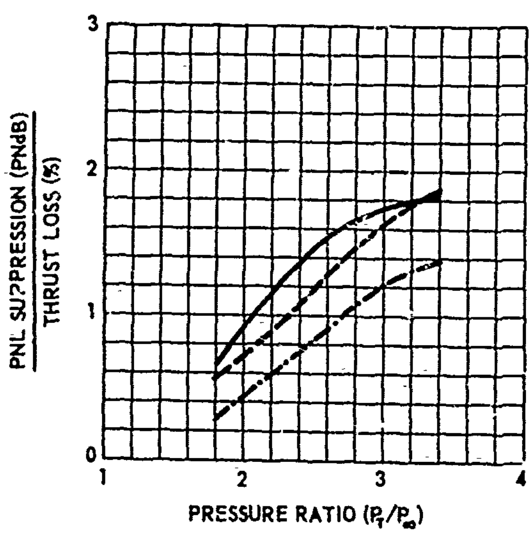


Description:

126 tubes with round convergent ends arranged in a hexagonal array.

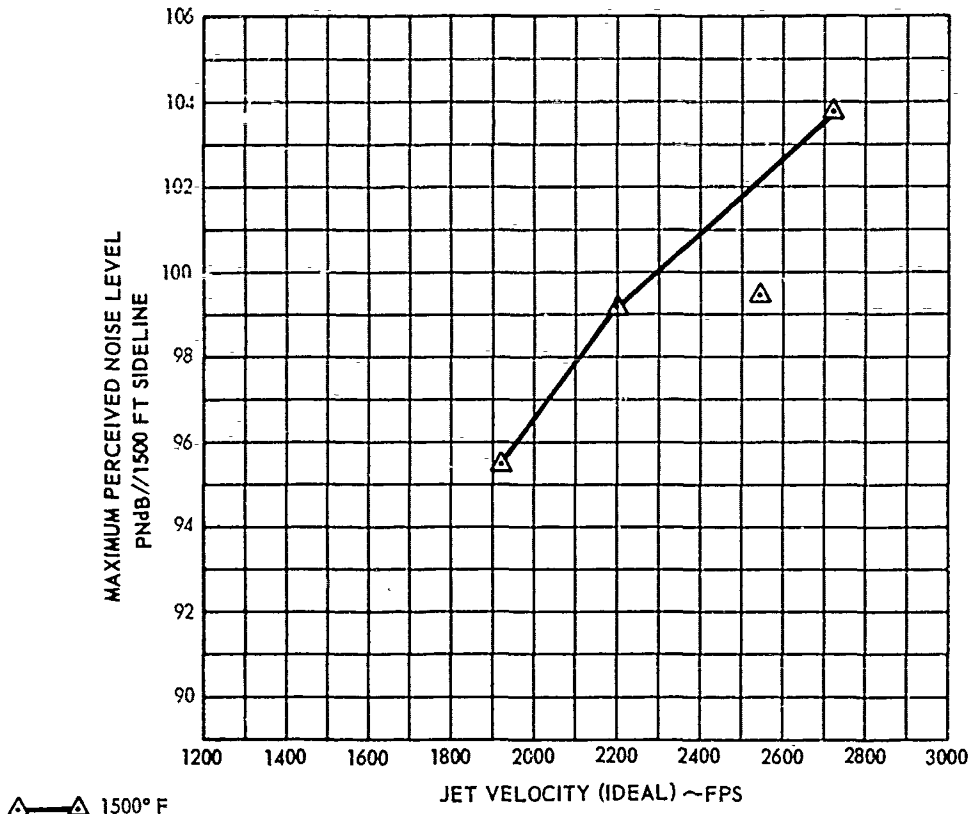
Area Ratio (A_T/A_P):	3.33
Flow Area (A_p):	28.1 inches
Tube Length:	7 inches



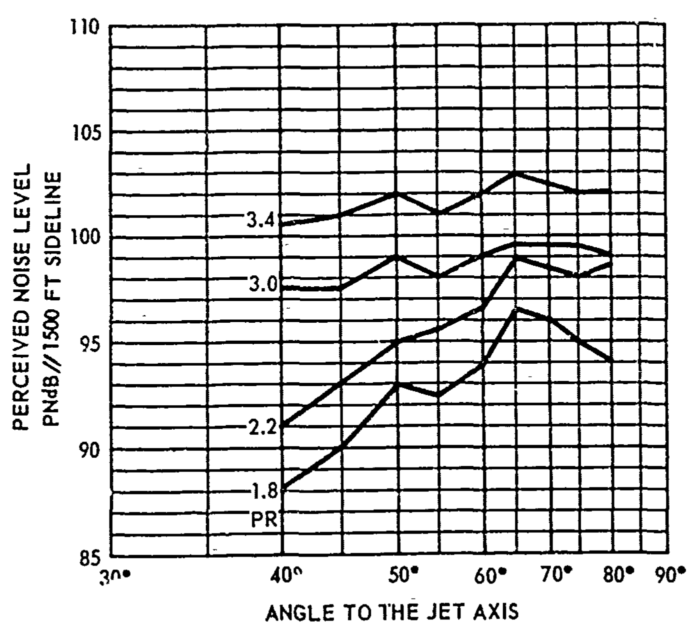


NOZZLE EXIT AREA (A_e): 12.6 FT^2
FREE FIELD VALUES

HM-AP-85-1 NOZZLE
(126 TUBE HEXAGON ARRAY)
AR 3.33
SCALE FACTOR: 8:1

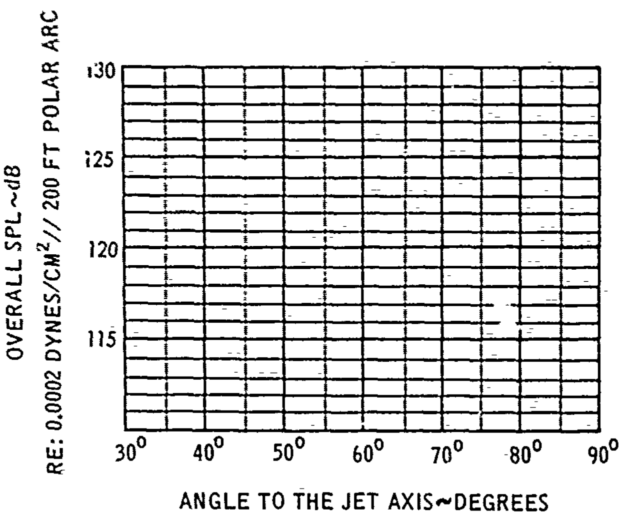


NOZZLE EXIT AREA (A_8): 12.6 FT²

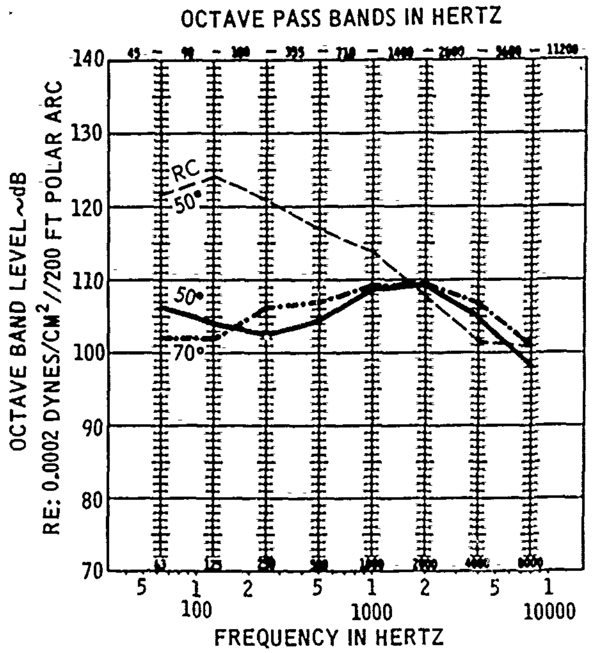


TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

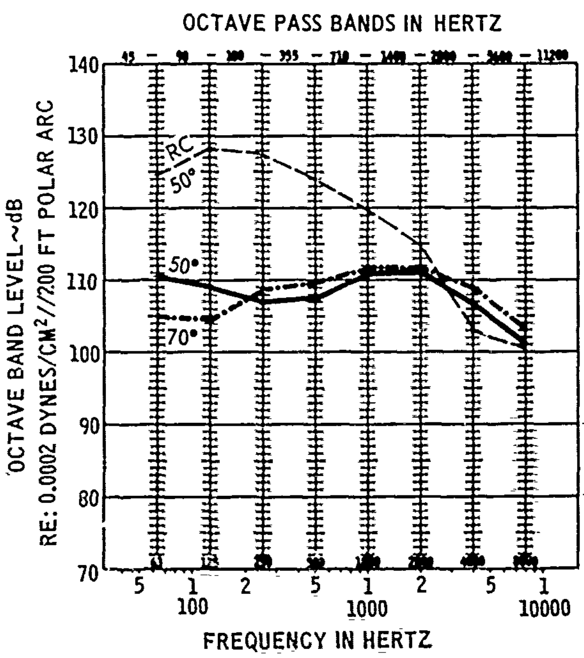


TOTAL TEMPERATURE (T_8) : 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT²

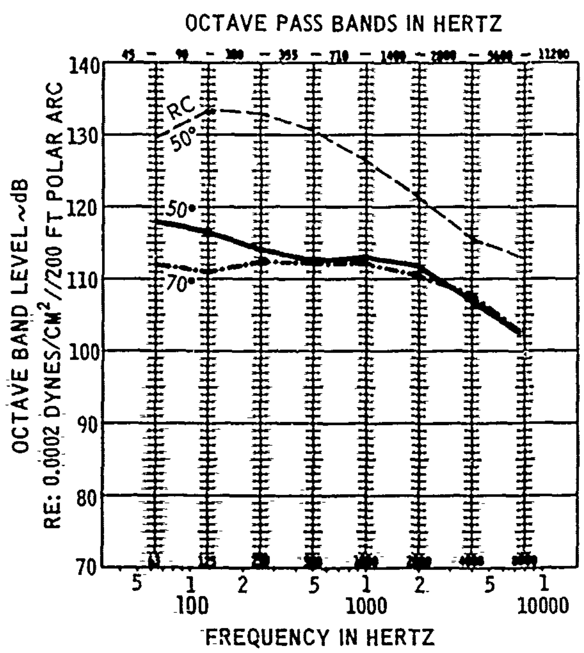


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 1923 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²

HM-AP-85-1 NOZZLE
(126 TUBE HEXAGON ARRAY)
AR 3.33
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2202 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1500° F
JET VELOCITY (IDEAL): 2555 FPS
NOZZLE EXIT AREA (A_8): 12.6 FT²

FREE FIELD VALUES

HM-AP-85-1 NOZZLE

(126 Tube Hexagon Array, AR 3.33)

Remarks:

The effective tube length was varied by blocking secondary air entrainment with a peripheral wall around the tube array. The blocker lengths tested were 4, 6, 7 and 9 inches. This resulted in effective tube lengths of 7 inches (no blocking), 3 inches, 1 inch, 0 inches and -2 inches. Although thrust loss was significantly affected by effective tube length, there was little noticeable change in jet noise levels until the blockers extended beyond the nozzle exit plane (Ref. D30). A tube length of -2 inches resulted in a sharp decrease in thrust and noise.

Acoustic test data taken with the HM-AP-85-1 (126 tube, AR 3.33) nozzle during September 1968 was compared to data acquired in February and March of 1969. (Ref. D31). Acoustic data agreed within ± 1.5 PNdB. There was very little difference noted in acoustic data obtained with convergent tube ends or straight (non-convergent) tube ends.

Ref. D32 relates the 126 tube nozzle PNL suppression with nozzle area ratio. Three area ratios were considered: 2.8, 3.33 and 5.2. Optimum area ratio at gas conditions of PR = 3.0 and T_T = 1500°F would occur at an area ratio of about 3.6 (14.8 PNdB suppression). The noise spectrum has a low frequency peak that is sensitive to pressure ratio and a high frequency peak that tends to agree with jet relationships (Strouhal number) prior to jet coalescence. The high frequency component of the spectrum peaks at a Strouhal number of 0.25, using the tube exit diameter as the dimension function. The low frequency part of the spectrum decreases in magnitude as area ratio increases.

Installation of a tight fitting ejector on the 126 tube, AR 3.33 nozzle improved PNL suppression by 1 to 2 PNdB, however, thrust loss increased (Ref. D34). The cylindrical ejector was 11 inches long and 12 inches in diameter. The effective primary nozzle diameter to ejector throat diameter ratio was 0.92. Addition of the ejector reduced the high frequency

noise levels, especially at the lower angles relative to the jet axis. Reference D35 discusses tests performed with various sizes of hardwall ejectors. The following ejectors were installed on the HM-AP-85-1 nozzle:

(1) 11 inches long, 12 inches diameter

(2) 16 inches long, 12 inches diameter

(3) 11 inches long, 13 inches diameter

The longer ejector installation resulted in a 1   1.5 PNdB reduction in PNL suppression relative to the shorter ejectors. Maximum 1500 foot sideline suppression attained was 15.8 PNdB with the 11 inch long by 13 inch diameter ejector configuration.

Elliptically shaped tubes did not noticeably change the noise characteristics. See Reference D33.

[redacted]-AP-[redacted]-1 NOZZLE

Test Facility: HNTF

Date: April 7, 1969

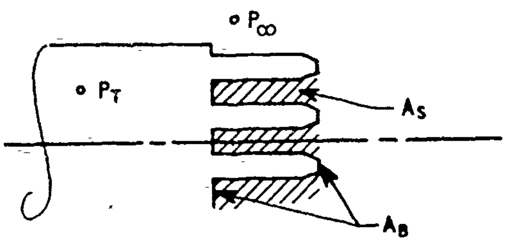
T_{amb}: 54°F

R.H.: 53%

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
84.1	1.8	1500°F	1923 fps	HM-AP-85-1
84.2	2.2	"	2202	"
84.3	2.6	"	2402	"
84.4	3.0	"	2555	"
84.5	3.4	"	2678	"
84.6	1.8	1000°F	1659	"
84.7	2.2	"	1900	"
84.8	2.6	"	2073	"
84.9	3.0	"	2205	"
84.10	3.4	"	2311	"
84.11	1.8	500°F	1345	"
84.12	2.2	"	1541	"
84.13	2.6	"	1681	"
84.14	3.0	"	1788	"
84.15	3.4	"	1850	"

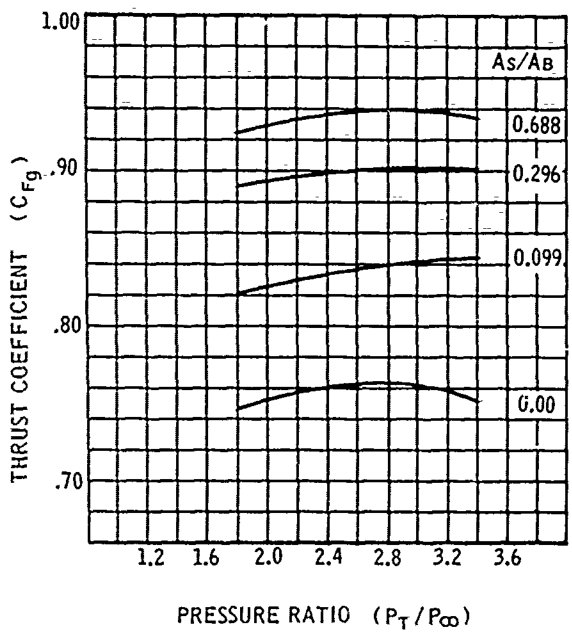
Run NO.	P_T/P	T_T	V_J (Ideal)	Nozzle
85.1	1.8	1500°F	1923 fps	6 Inch Round Convergent Nozzle
85.2	2.2	"	2202	"
85.3	2.6	"	2402	"
85.4	3.0	"	2555	"
85.5	3.4	"	2678	"
85.6	1.8	1000°F	1659	"
85.7	2.2	"	1900	"
85.8	2.6	"	2073	"
85.9	3.0	"	2205	"
85.10	3.4	"	2311	"
85.11	1.8	500°F	1345	"
85.12	2.2	"	1541	"
85.13	2.6	"	1681	"
85.14	3.0	"	1788	"
85.15	3.4	"	1850	"

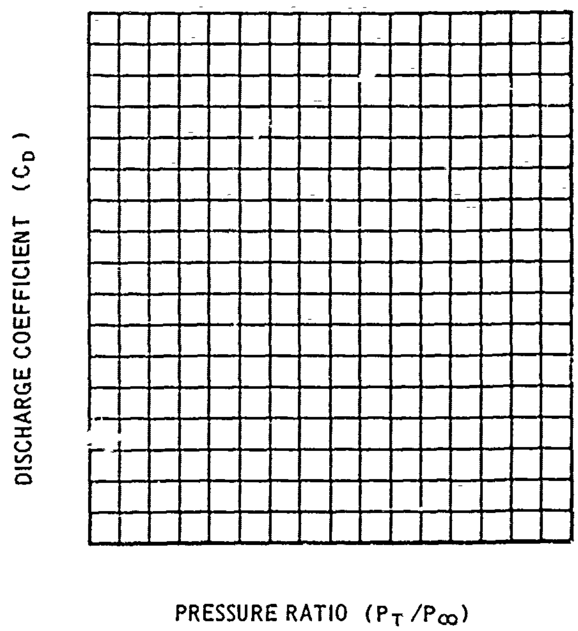
HM-AP-85-1 WITHOUT EJECTOR

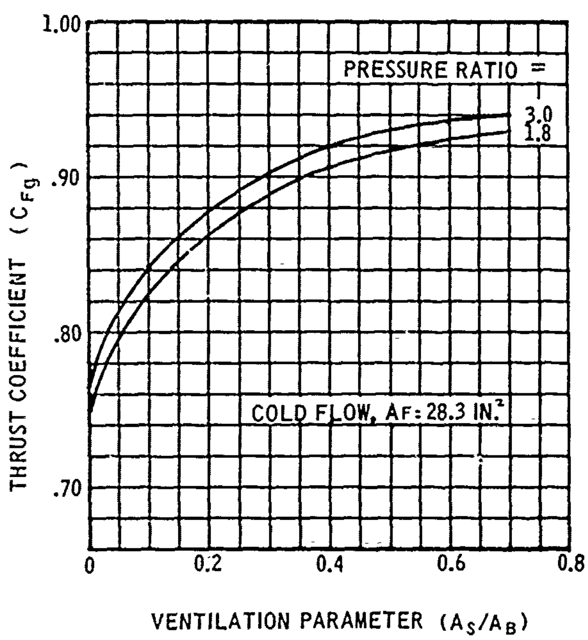


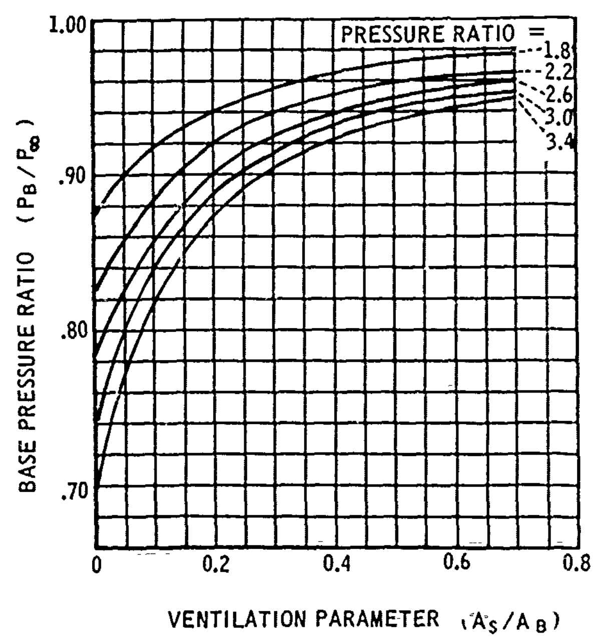
$$C_{Fg} = \frac{\text{(THRUST-DRAG) MEASURED}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{\text{(MASS FLOW) MEASURED}}{\text{IDEAL PRIMARY MASS FLOW}}$$

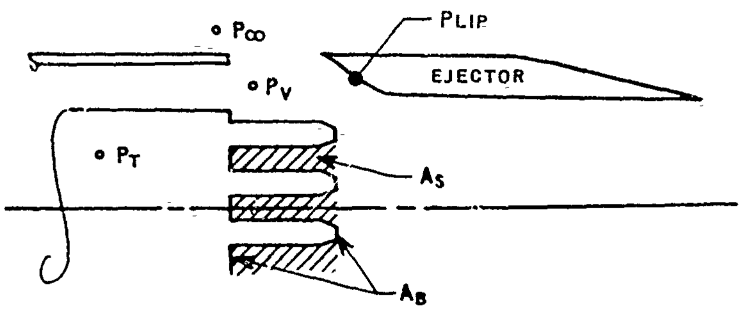








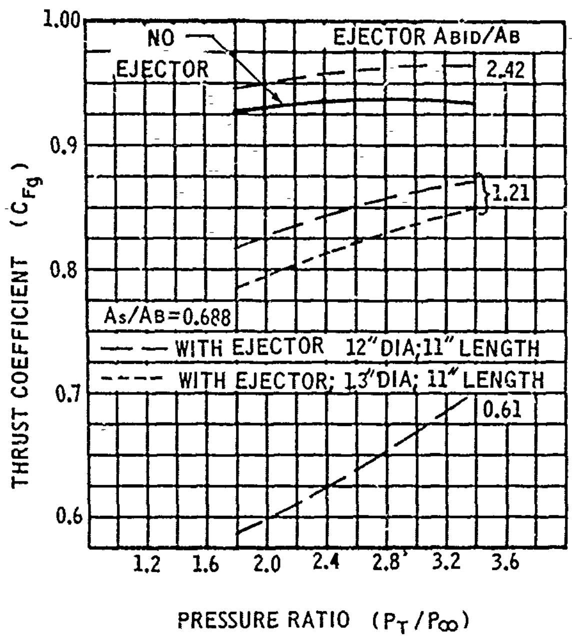
HM-AP-85-1 WITH EJECTOR

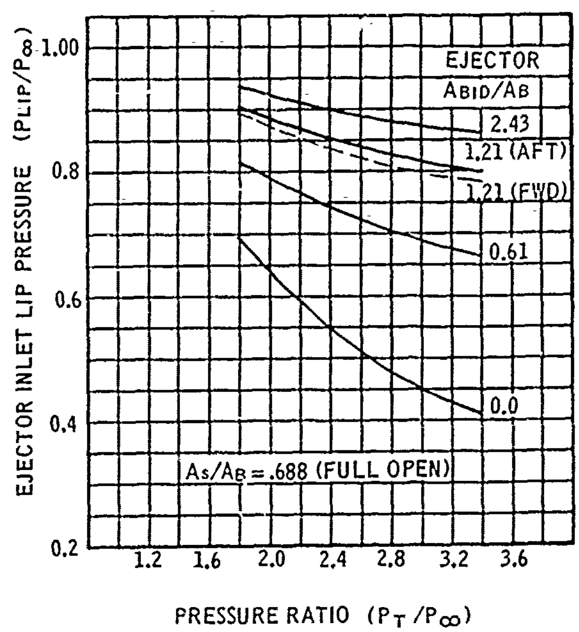


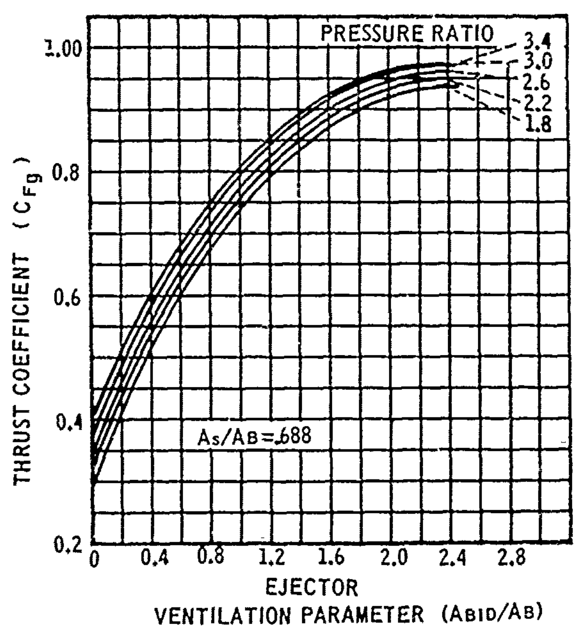
ABID = EJECTOR BLOW-IN DOOR FLOW AREA

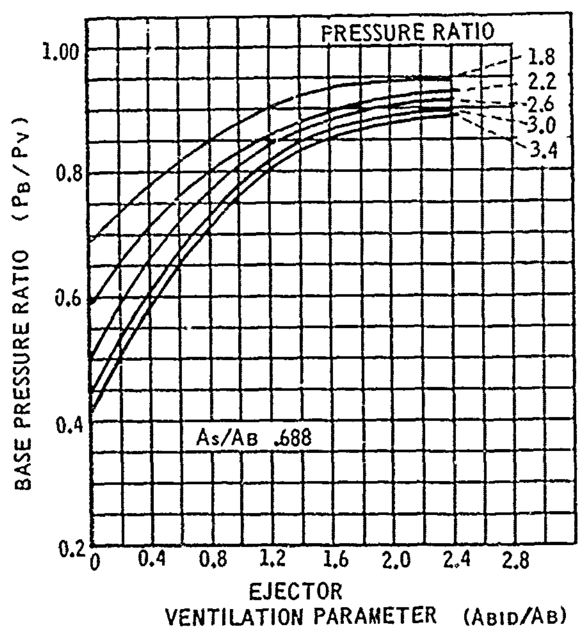
$$C_{F_g} = \frac{\text{(THRUST–DRAG) MEASURED}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{\text{(MASS FLOW) MEASURED}}{\text{IDEAL PRIMARY MASS FLOW}}$$



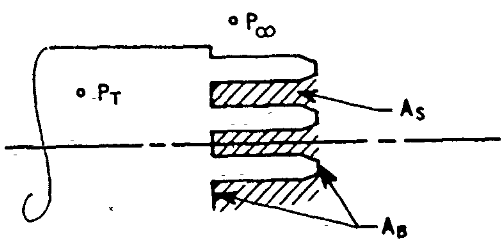






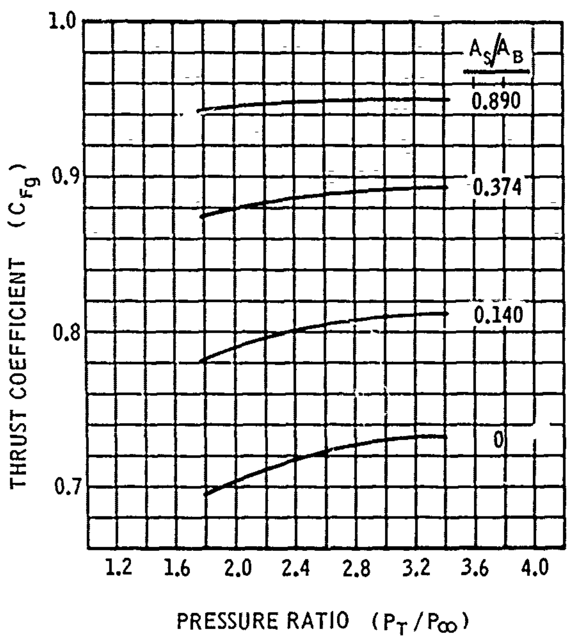
HM-AP-85-2

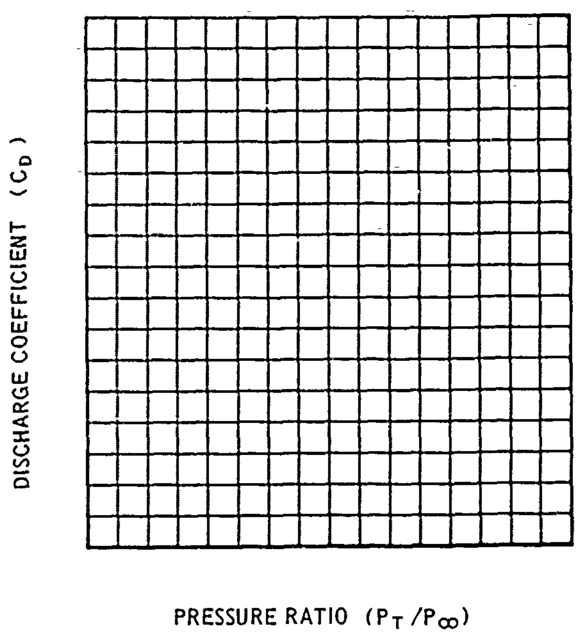
126.7-IN. TUBES, AR 5.2
HEXAGONAL ARRAY
NO EJECTOR

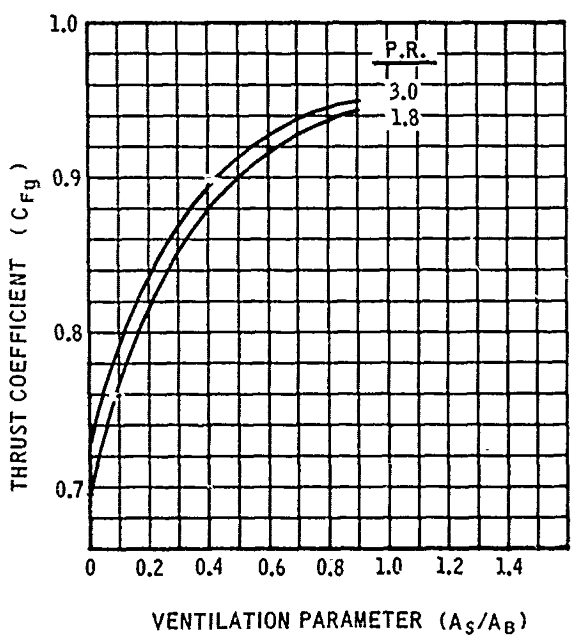


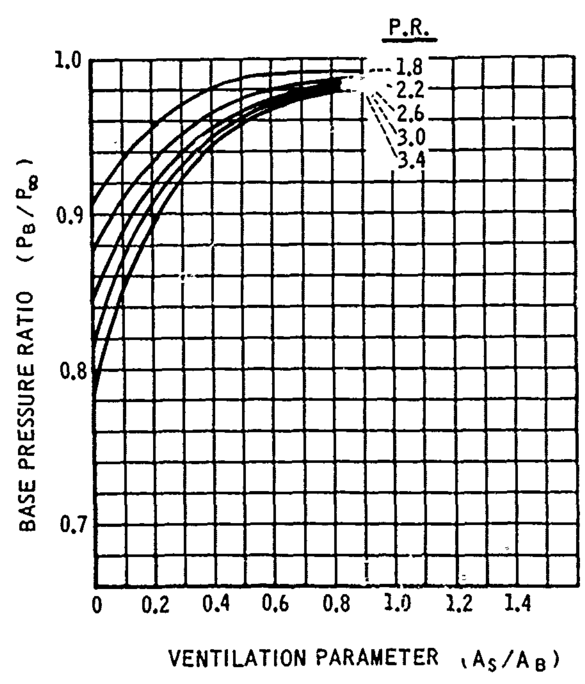
$$C_{Fg} = \frac{\text{(THRUST-DRAG) MEASURED}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{\text{(MASS FLOW) MEASURED}}{\text{IDEAL PRIMARY MASS FLOW}}$$

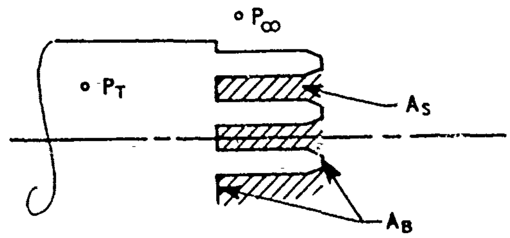








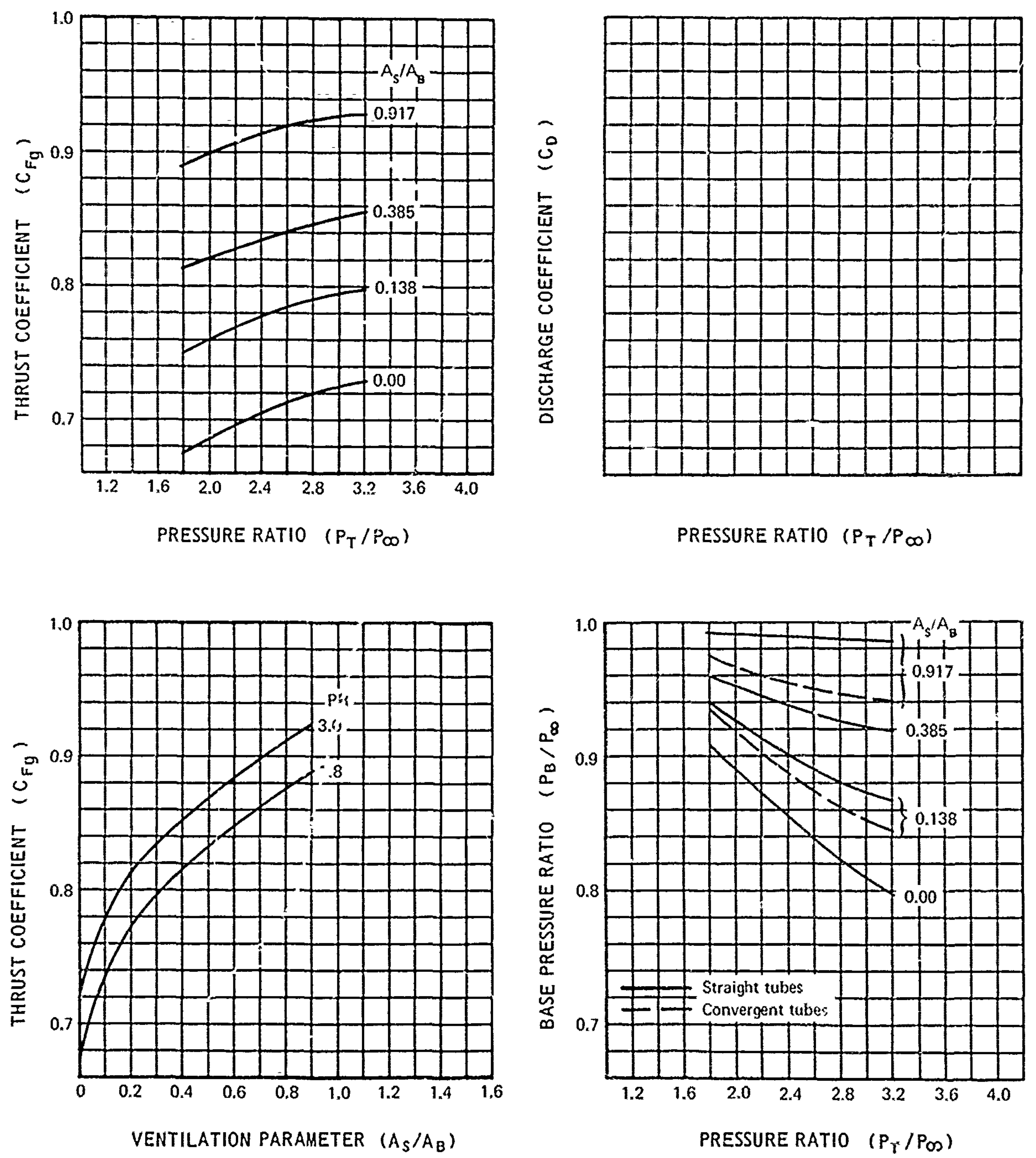
HM - AP - 85-3



126-7" JBES, AR = 4.4
HEXAGONAL ARRAY
NO EJECTOR

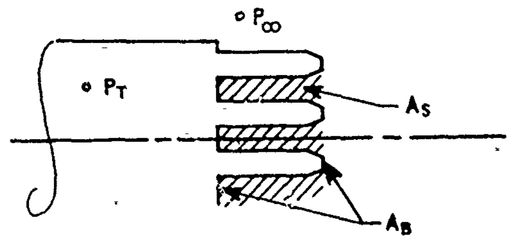
$$C_{F_g} = \frac{(\text{THRUST} - \text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



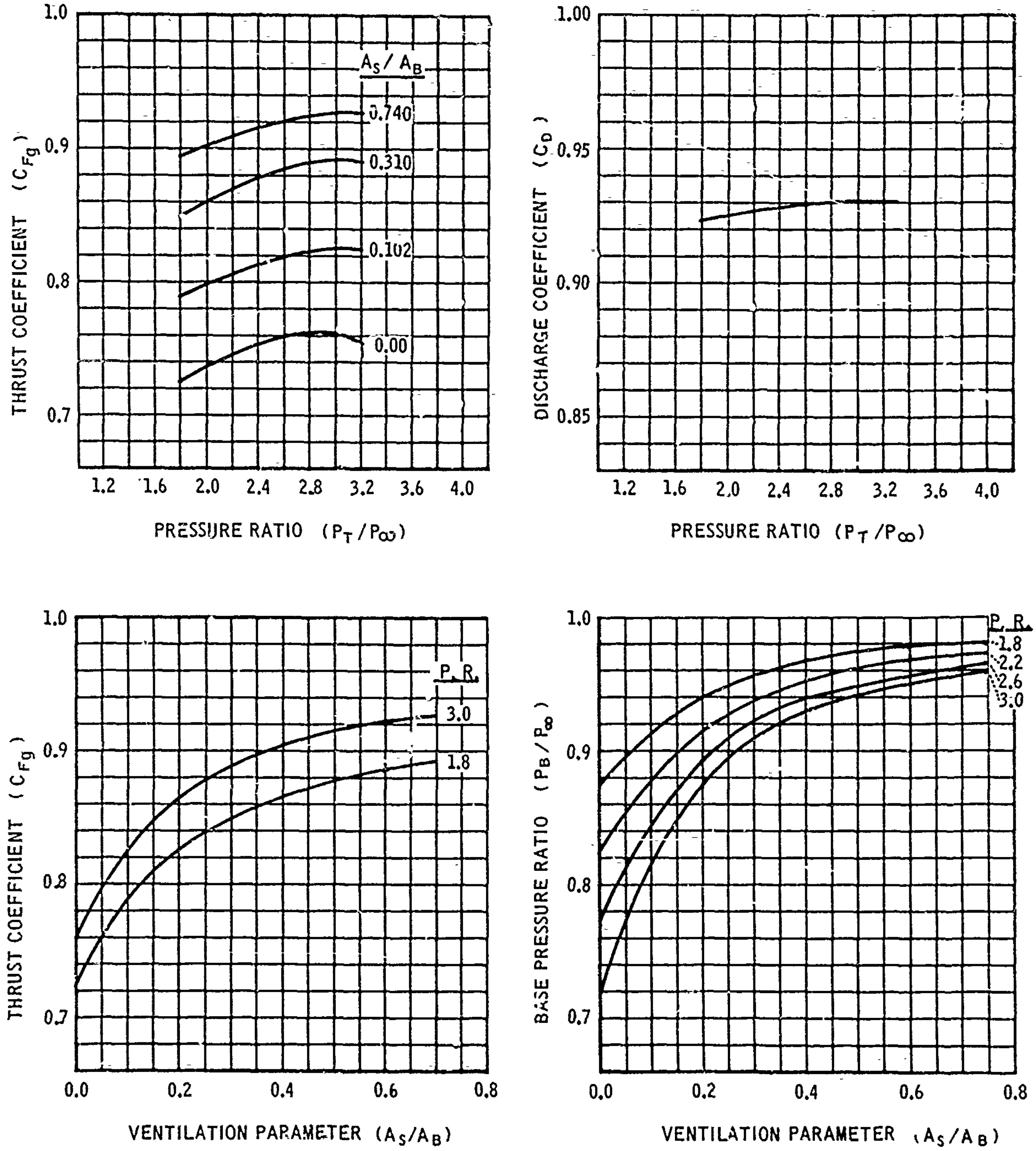
HM - AP - 85 - 4 NO EJECTOR

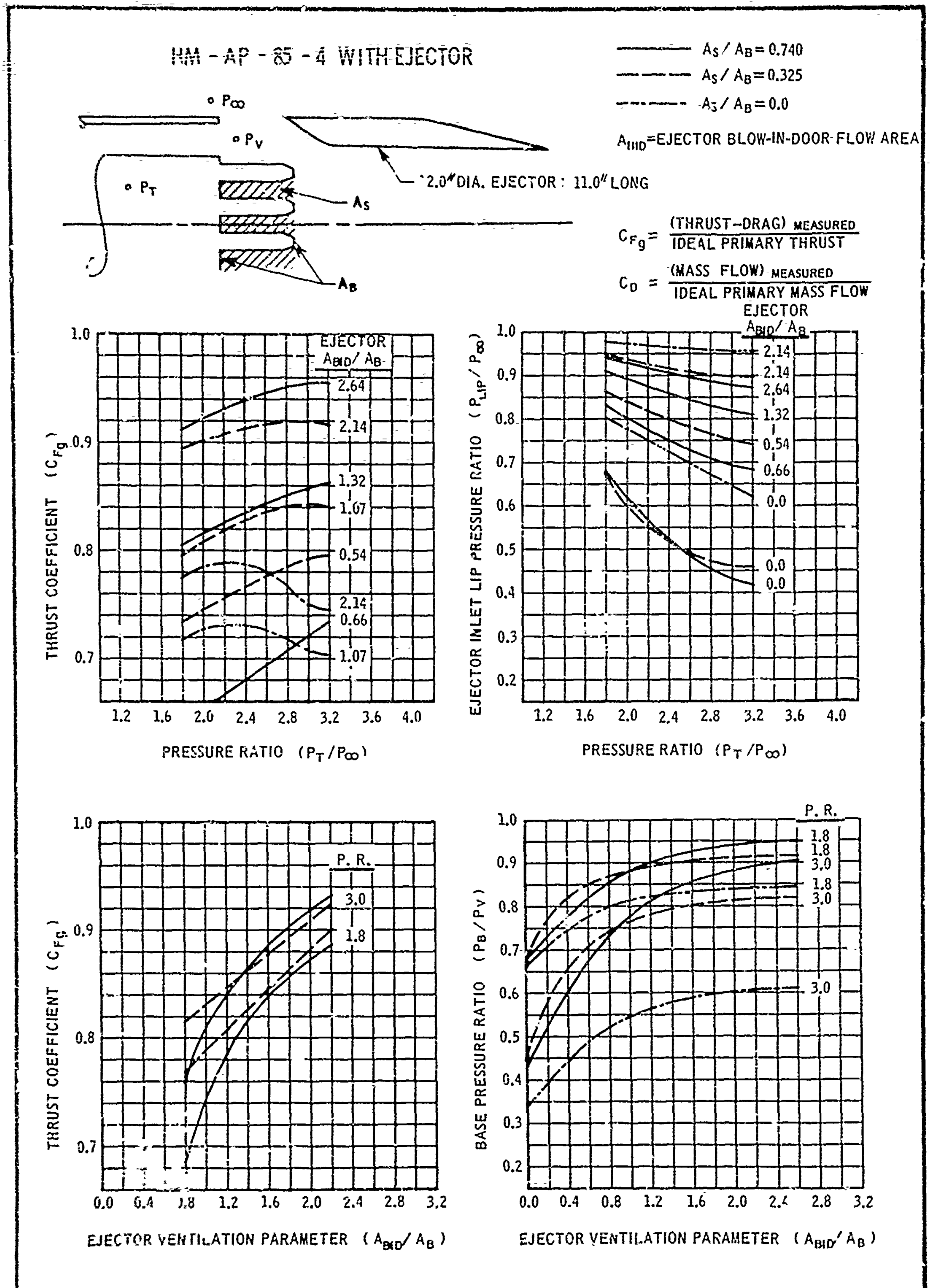
7 IN. NON-CONVERGENT
126-TUBES, AR 2.1
HEXAGONAL ARRAY
NO EJECTOR



$$C_{Fg} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

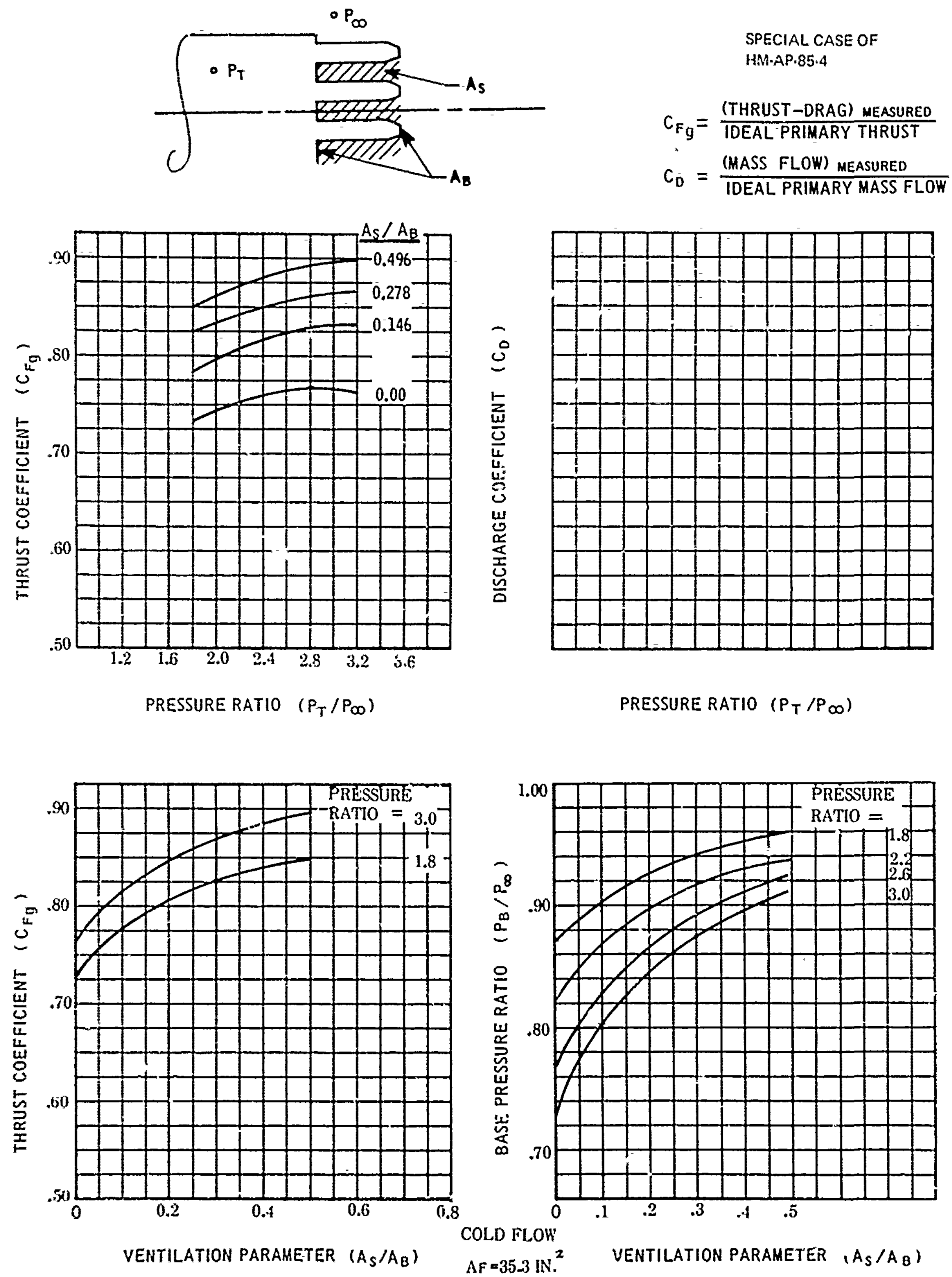
$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$





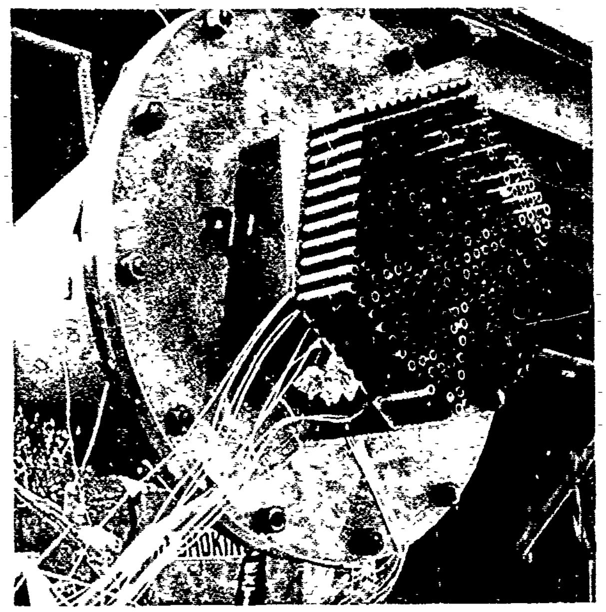
HM - AP - 85 - 4 WITH EJECTOR
As / AB = 0.740
As / AB = 0.325
As / AB = 0.0
ABID = EJECTOR BLOW-IN-DOOR FLOW AREA
P∞
PV
PT
As
AB
2.0" DIA. EJECTOR : 11.0" LONG
CFg = (THRUST–DRAG) MEASURED / IDEAL PRIMARY THRUST
CD = (MASS FLOW) MEASURED / IDEAL PRIMARY MASS FLOW
EJECTOR
ABID / AB
2.64
2.14
1.32
1.07
0.54
2.14
0.66
1.07
THRUST COEFFICIENT (CFg)
PRESSURE RATIO (PT / P∞)
EJECTOR
ABID / AB
2.14
2.14
2.64
1.32
0.54
0.66
0.0
0.0
0.0
EJECTOR INLET LIP PRESSURE RATIO (PLIP / P∞)
PRESSURE RATIO (PT / P∞)
P. R.
3.0
1.8
THRUST COEFFICIENT (CFg)
EJECTOR VENTILATION PARAMETER (ABID / AB)
P. R.
1.8
1.8
3.0
1.8
3.0
3.0
BASE PRESSURE RATIO (PB / PV)
EJECTOR VENTILATION PARAMETER (ABID / AB)

126 TUBE, AREA RATIO =2.8, 3" ELLIPTICAL TUBES



HM-AP-86-1 NOZZLE

(330 TUBE HEXAGONAL ARRAY, AR4.0)



Description:

The HM-AP-86-1 nozzle is a 330 tube hexagonal array with equal spacing between tubes. The tubes have round convergent ends and are inserted into a baseplate. The baseplate attaches to a diffusing plenum which provides the transition from the gas supply line to the baseplate.

Number of Elements: 330 tubes with round convergent ends

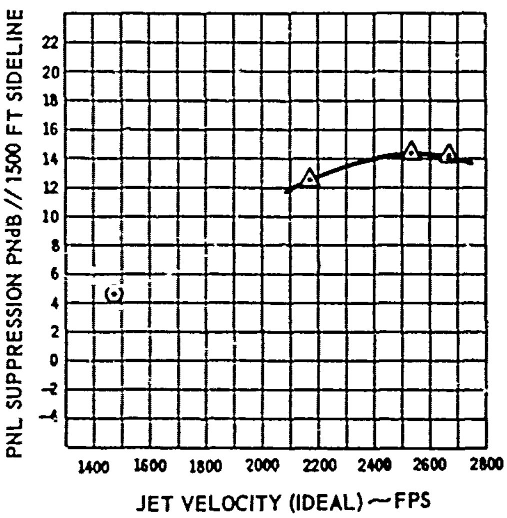
Area Ratio: 4.0

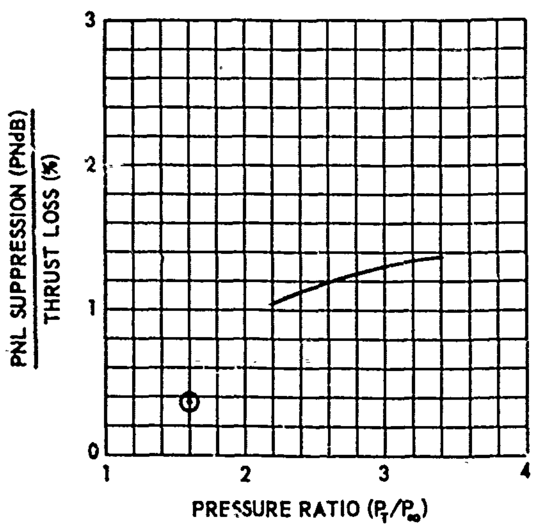
Flow Area: 28.3 square inches

Exit Cant Angle: 0 degrees

Length of Tubes: 7 inches

Material: 321 CRES

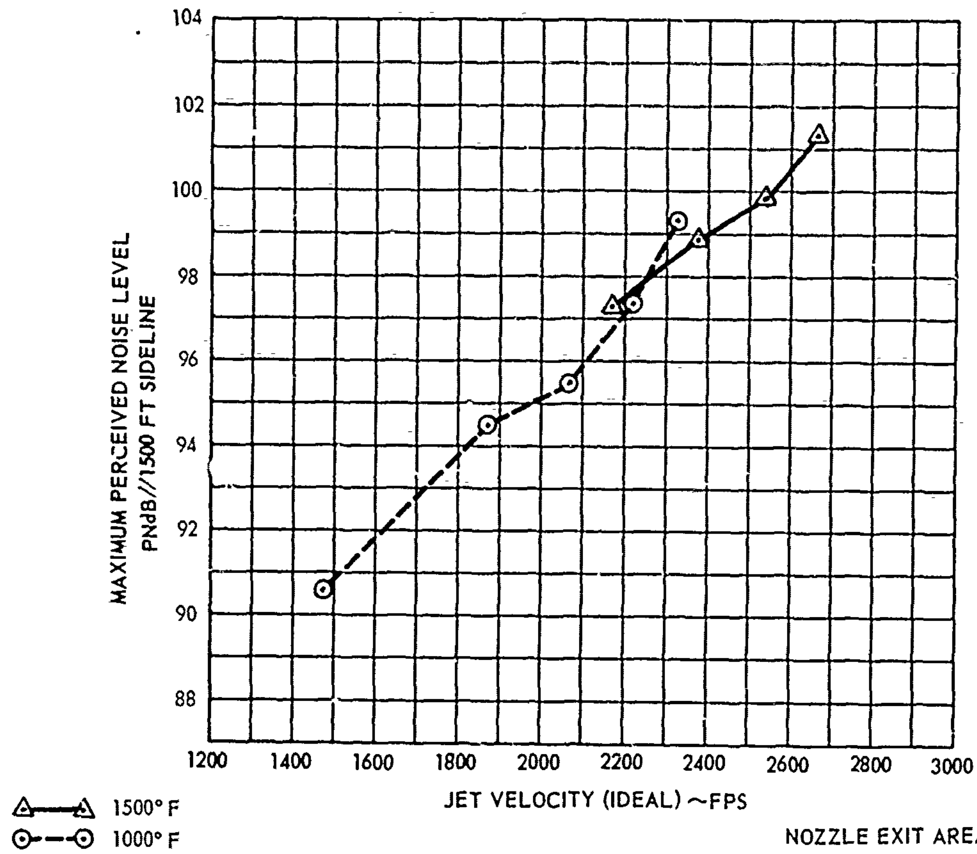




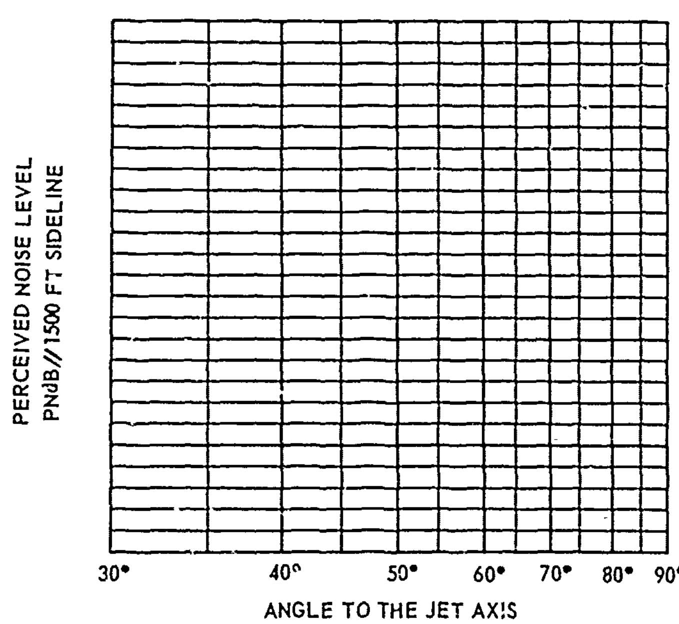
1500° F
1000° F

NOZZLE EXIT AREA (A_e): 12.6 FT^2
FREE FIELD VALUES

HM-AP-86-1 NOZZLE
(330 TUBE HEXAGONAL ARRAY)
AR 4.0
SCALE FACTOR: 8:1



NOZZLE EXIT AREA (A_8): 12.6 FT^2



TOTAL TEMPERATURE (T_8): 1500° F
NOZZLE EXIT AREA (A_8): 12.6 FT^2

FREE FIELD VALUES

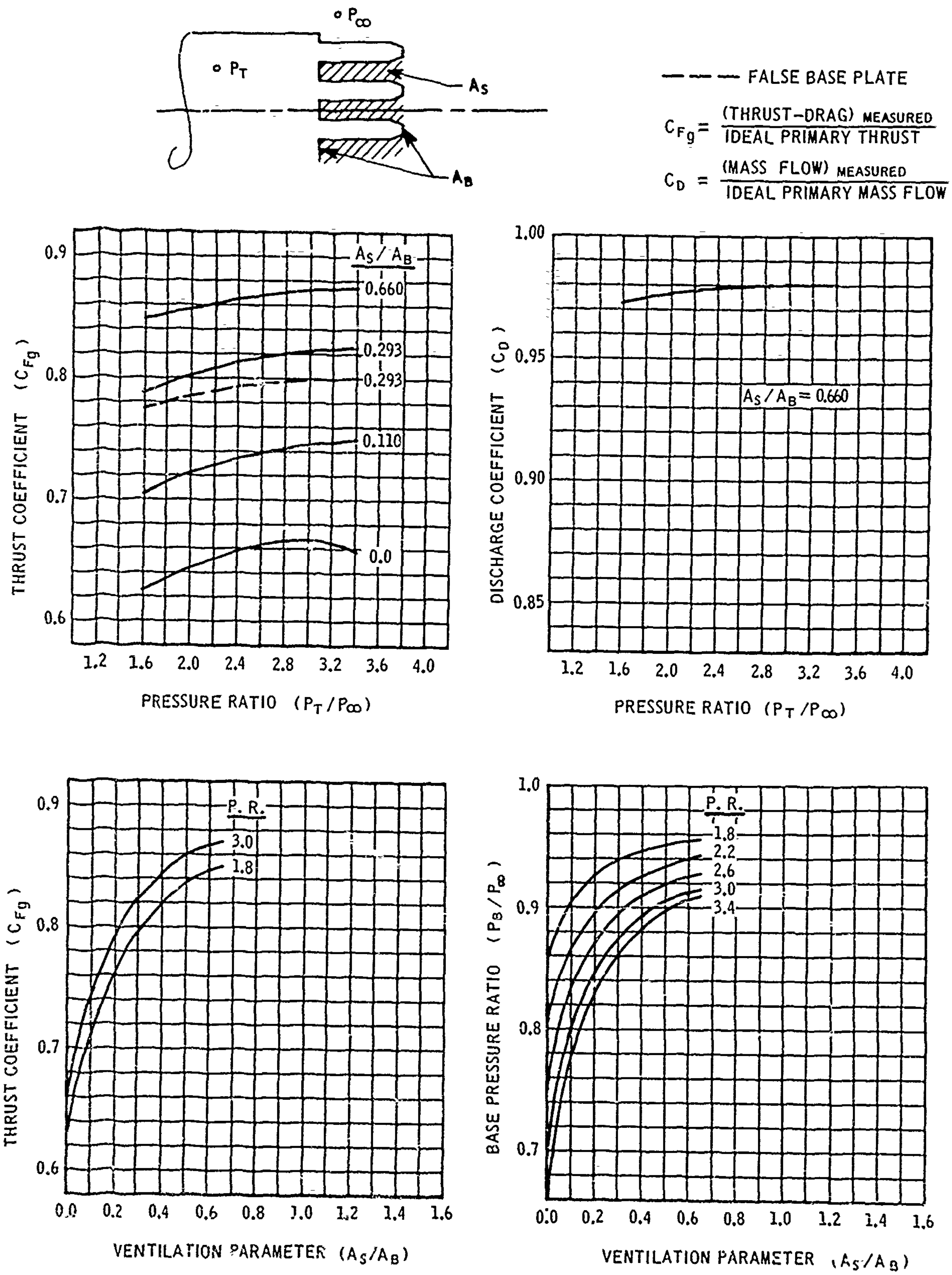
HM-AP-86-1 NOZZLE

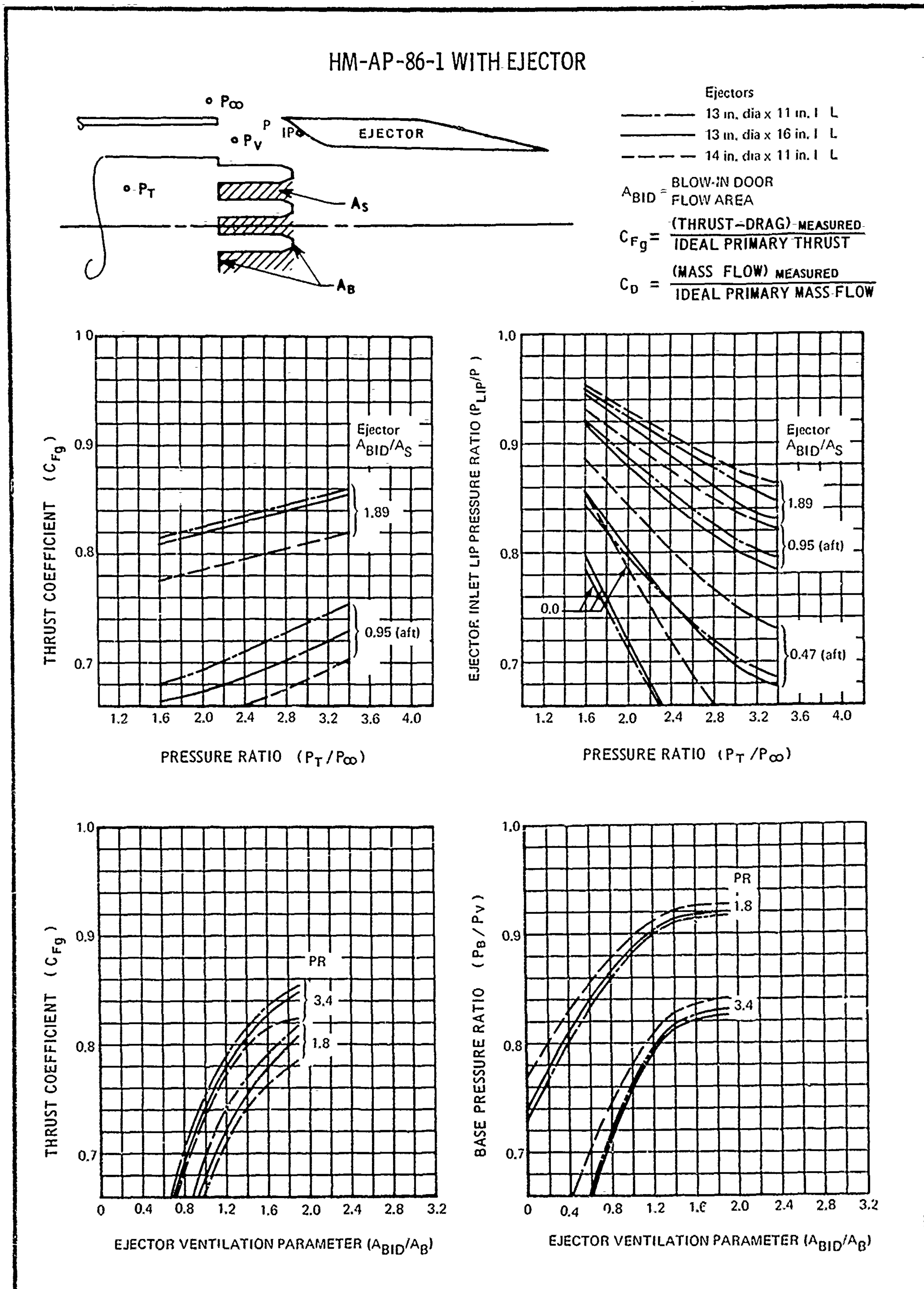
(330 Tube Hexagonal Array, AR 4.0)

Remarks

Measured acoustic data for the HM-AP-86-1 nozzle has been lost. Most of the information on this nozzle was derived from Reference D36. Several ejectors were tested with this nozzle. Hexagonal unlined ejectors with lengths of 5, 12.9 and 25.8 inches attained up to 1 PNdB, 4 PNdB and 5 PNdB respectively at low pressure ratios, e.g. PR = 1.6, T_T = 1000°F. At pressure ratios of 3.0 and 3.4 the unlined ejectors provided 1 PNdB or less additional suppression. The same ejectors with one-inch thick fiberglass installed on the inner walls significantly improved suppression values. The lined 5-inch ejector improved suppression by 1 PNdB relative to the unlined case. The 12.9" lined ejector improved suppression by 2 - 3 PNdB. The 25.8 inch ejector improved suppression by 5 - 6.5 PNdB. The ejector throat dimension in all cases was 11.8 inches. Maximum PNL suppression of 20.5 PNdB was realized by the HM-AP-86-1 nozzle with lined 25.8 inch long ejector at pressure ratios of 2.2 and 3.0 with T_T = 1500°F.

HM - AP - 86 - I NO EJECTOR




HM-AP-86-1 WITH EJECTOR
Ejectors
13 in. dia x 11 in. L
13 in. dia x 16 in. L
14 in. dia x 11 in. L
A_{BID} = BLOW-IN DOOR FLOW AREA
$C_{Fg} = \frac{\text{(THRUST – DRAG) MEASURED}}{\text{IDEAL PRIMARY THRUST}}$
$C_D = \frac{\text{(MASS FLOW) MEASURED}}{\text{IDEAL PRIMARY MASS FLOW}}$
EJECTOR
P_∞
P_V
P_T
A_S
A_B
THRUST COEFFICIENT (C_{Fg})
PRESSURE RATIO (P_T/P_∞)
Ejector A_{BID}/A_S
1.89
0.95 (aft)
EJECTOR INLET LIP PRESSURE RATIO (P_{LIP}/P)
0.47 (aft)
0.0
EJECTOR VENTILATION PARAMETER (A_{BID}/A_B)
PR
3.4
1.8
BASE PRESSURE RATIO (P_B/P_V)

HM-AP-86-2 NOZZLE

(330 TUBE HEXAGONAL ARRAY, AR 5.2)

Description:

The HM-AP-86-2 nozzle is a 330 tube hexagonal array with equal spacing between tubes. The tubes have round convergent ends and are inserted into a baseplate. The baseplate attaches to a diffusing plenum which provides the transition from the gas supply line to the baseplate.

Number of Elements: 330 tubes with round convergent ends

Area Ratio: 5.2

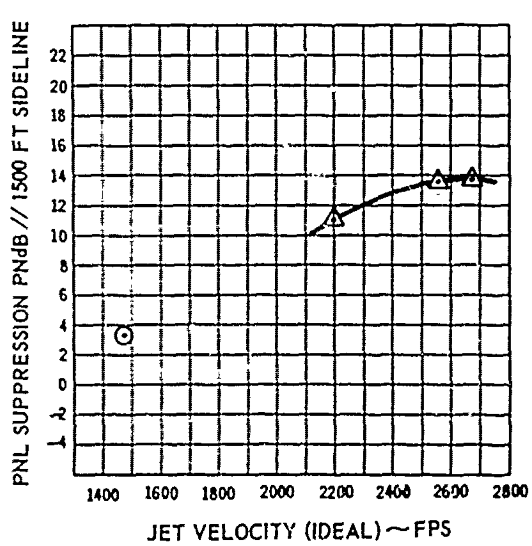
Flow Area: 28.3 square inches

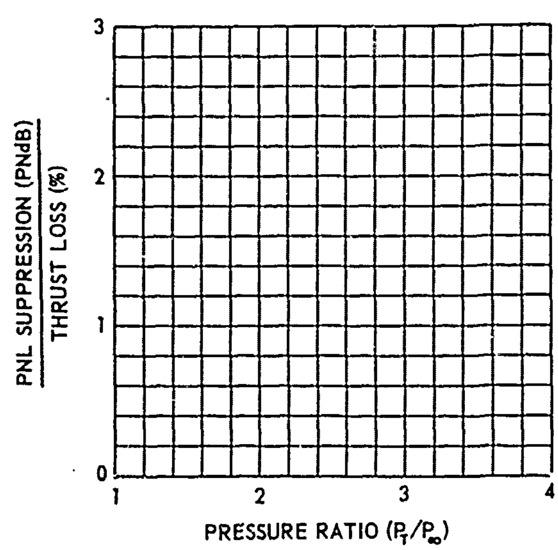
Exit Cant Angle: 0 degrees

Length of Tubes: 7 inches

Material: 321 CRES

NO PICTURE AVAILABLE





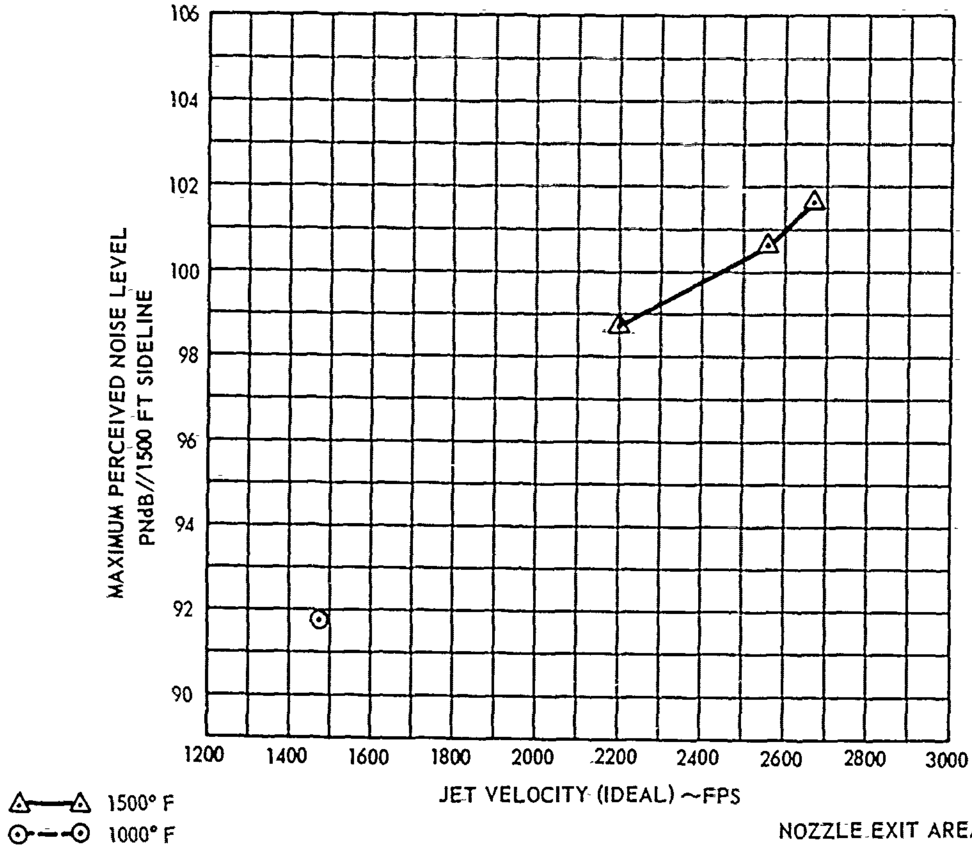
△—△ 1500° F

⊙--⊙ 1000° F

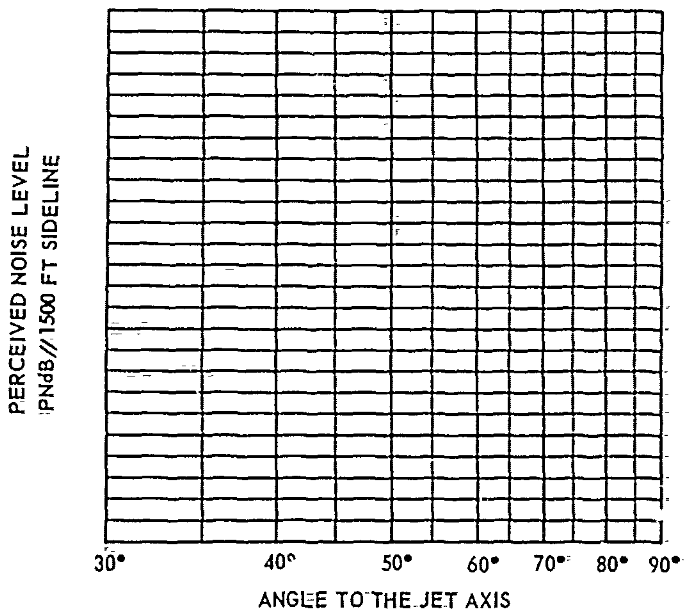
NOZZLE EXIT AREA (A_8): 12.6 FT^2

FREE FIELD VALUES

HM-AP-86-2 NOZZLE
(330 TUBE HEXAGONAL ARRAY)
AR 5.2
SCALE FACTOR: 8:1



NOZZLE EXIT AREA (A_8): 12.6 FT^2



TOTAL TEMPERATURE (T_8): 1500° F
NO. 'LE EXIT AREA (A_8): 12.6 FT^2

FREE FIELD VALUES

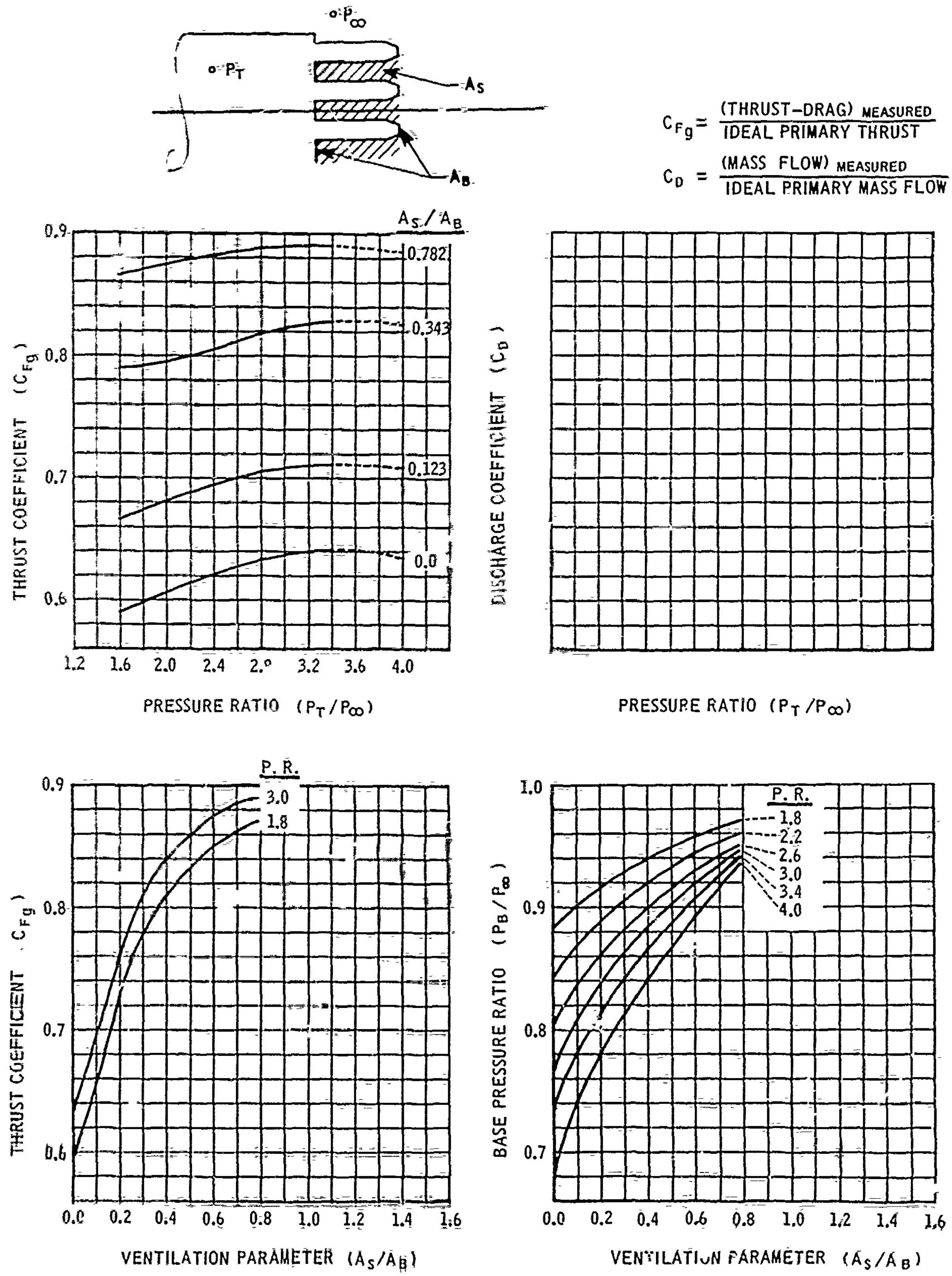
HM-AP-86-2

(330 Tube Hexagonal Array, AR 5.2)

Remarks

Measured acoustic data for the HM-AP-86-2 nozzle has been lost. Extrapolated PNL values are included in Reference D36.

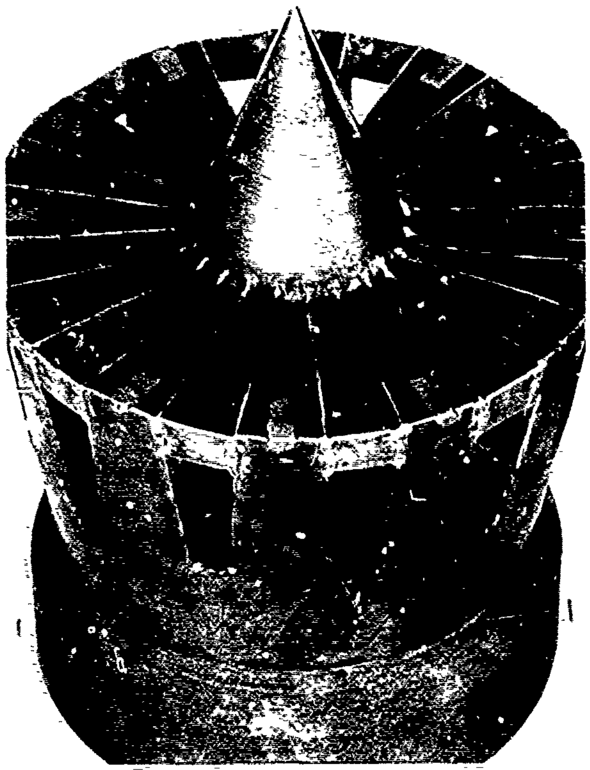
HM - AP - 86 - 2



P_∞
P_T
A_S
A_B
$C_{Fg} = \frac{\text{(THRUST-DRAG) MEASURED}}{\text{IDEAL PRIMARY THRUST}}$
$C_D = \frac{\text{(MASS FLOW) MEASURED}}{\text{IDEAL PRIMARY MASS FLOW}}$
A_S / A_B
0.782
0.343
0.123
0.0
THRUST COEFFICIENT (C_{Fg})
PRESSURE RATIO (P_T/P_∞)
DISCHARGE COEFFICIENT (C_D)
PRESSURE RATIO (P_T/P_∞)
P. R.
3.0
1.8
THRUST COEFFICIENT (C_{Fg})
VENTILATION PARAMETER (A_S/A_B)
P. R.
1.8
2.2
2.6
3.0
3.4
4.0
BASE PRESSURE RATIO (P_B/P_∞)
VENTILATION PARAMETER (A_S/A_B)

MAE 4A NOZZLE

(12SPOKES AND CENTER PLUG, AR 2.9)



Description:

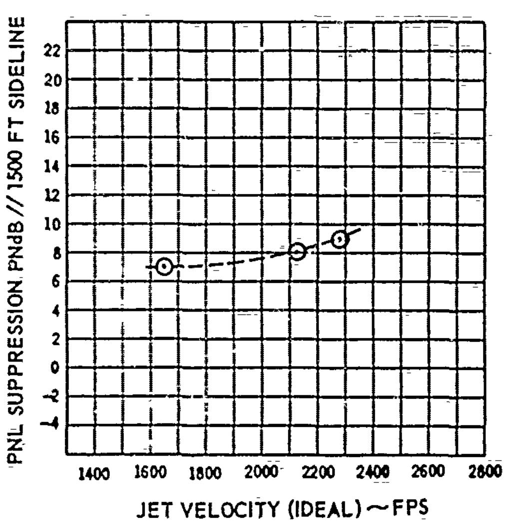
Number of Elements: 12 spokes with conical center plug

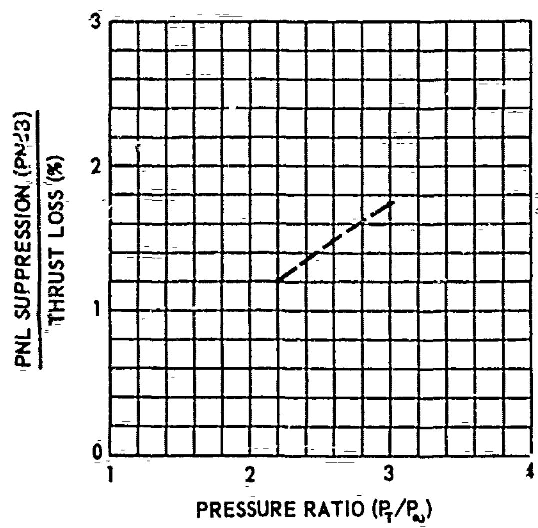
Area Ratio: 2.9

Spoke Penetration: 65%, termina-tine at center plug

Flow Area: 6.707 square inches

Exit Cant Angle: 0 degrees



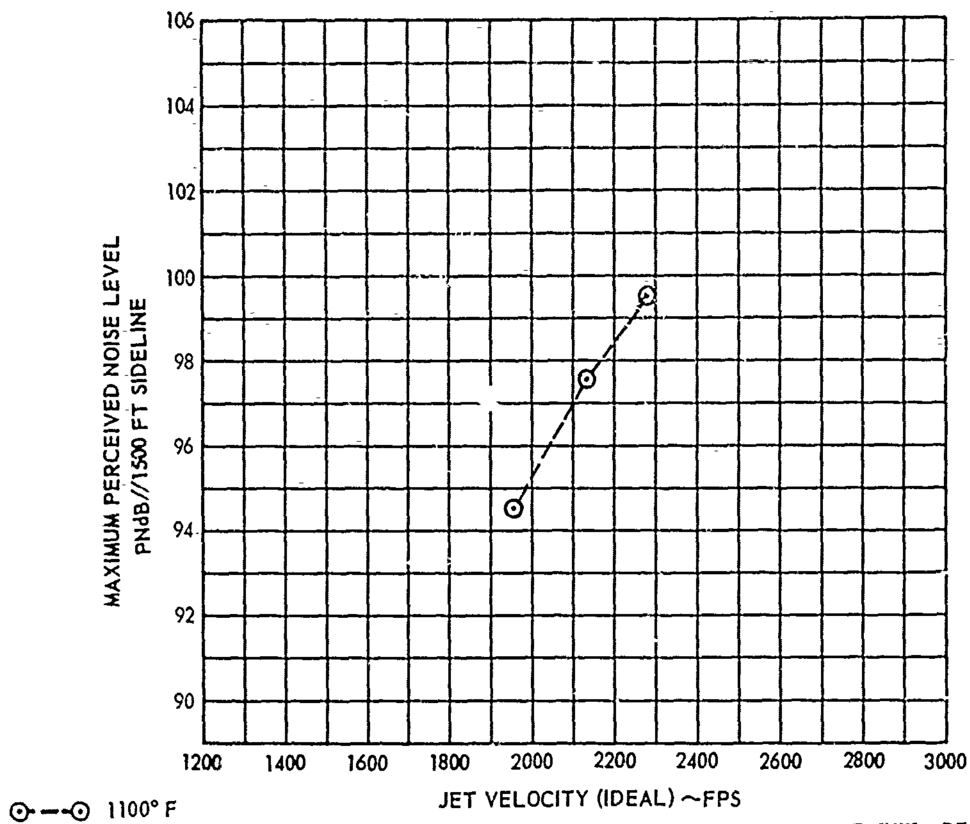


⊙--⊙ 1100° F

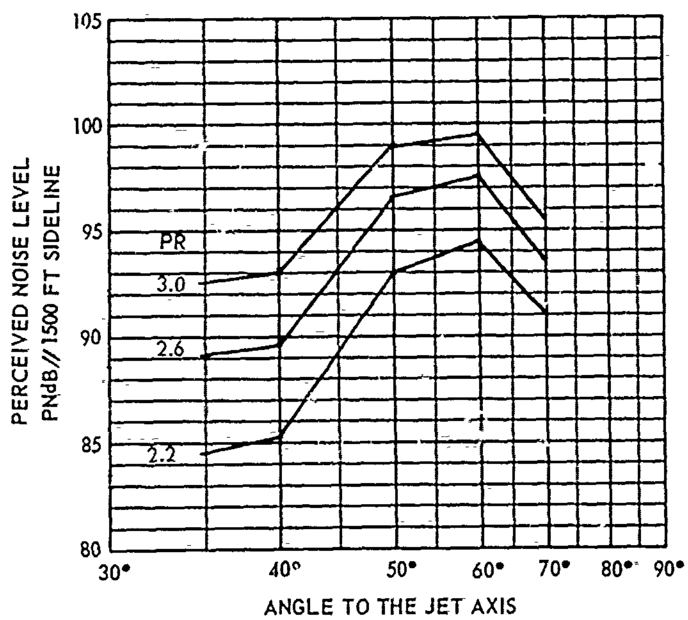
NOZZLE EXIT AREA (A_e): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

MAE 4A NOZZLE
(12 SPOKES AND CENTER PLUG)
AR 2.9
SCALE FACTOR: 8:1

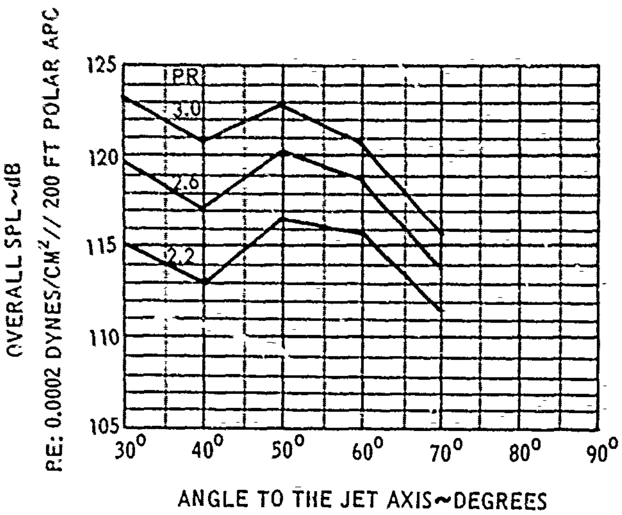


NOZZLE EXIT AREA (A_8): 3.3 FT^2

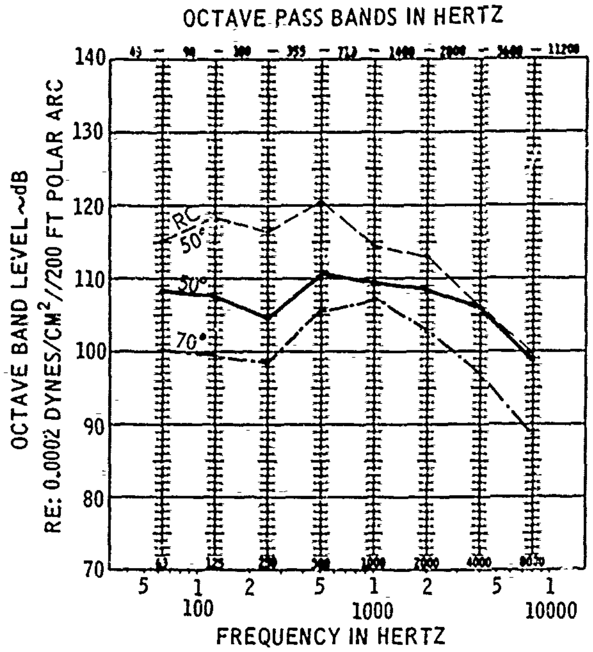


TOTAL TEMPERATURE (T_8): 1100° F
NOZZLE EXIT AREA (A_8): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

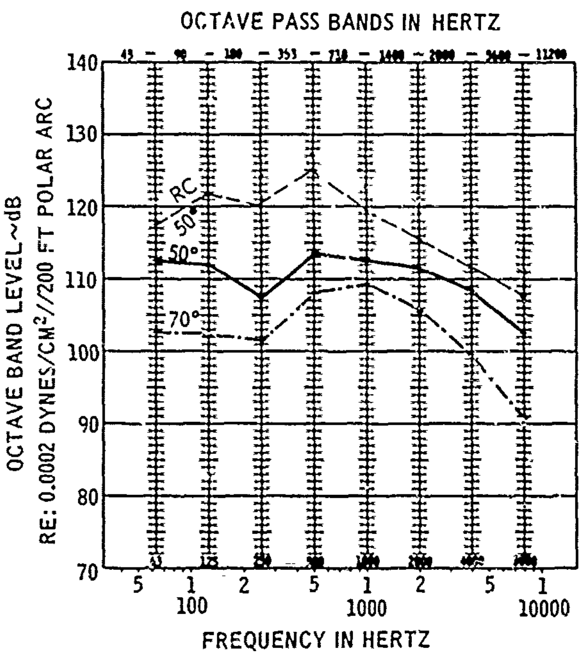


TOTAL TEMPERATURE (T_8) : 1100° F
NOZZLE EXIT AREA (A_8): 3.3 FT^2

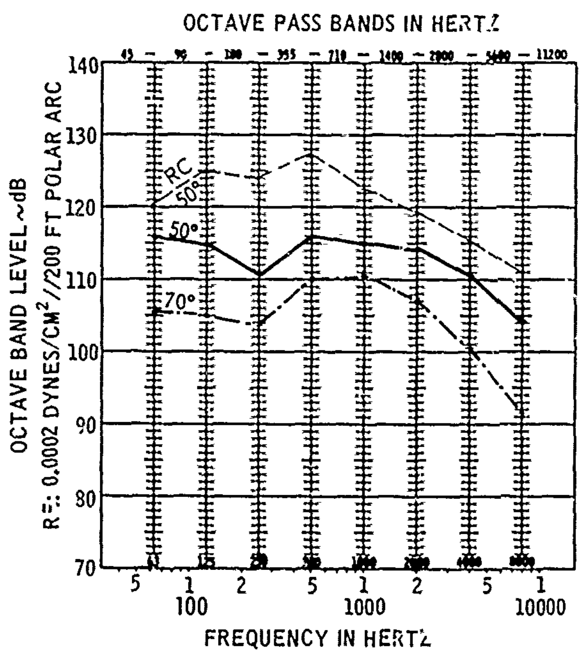


PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1100° F
JET VELOCITY (IDEAL): 1960 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT^2

MAE 4A NOZZLE
(12 SPOKES AND CENTER PLUG)
AR 2.9
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1100° F
JET VELOCITY (IDEAL): 2130 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT^2



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1100° F
JET VELOCITY (IDEAL): 2280 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

(12 Spoke and Center Plug, AR 2.9)

Remarks

Acoustic characteristics were reported in Reference D37.

MAE-4A

Facility: Annex D (Cell #1)
Nozzle and Microphone Heights are 20 Inches

Date:

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H 170	2.2	1100°F	1960 fps	MAE 4A
H 171	2.6	"	2130	"
H 172	3.0	"	2280	"
H 164	2.2	1100°F	1960 fps	3.08-In. Round Convergent Nozzle*
H 165	2.6	"	2130	"
H 166	3.0	"	2280	"

*1/8th scale C-6

Measured acoustic data is recorded in Reference D2.

NOZZLE TEST DATA

OCTAVE BAND LEVEL—dB RE: 0.0002 DYNES/CM^2//25 FT

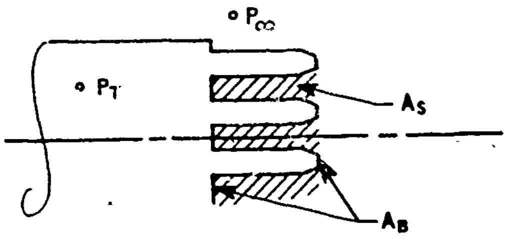
MAE-4A

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H164 L30	125.9	117.6	120.3	117.5	121.2	114.7	108.3	104.2	98.7
H164 L40	123.9	115.9	118.8	115.6	119.0	110.6	100.8	93.2	94.1
H164 L50	124.9	115.0	118.4	116.7	120.4	114.2	113.1	106.3	99.8
H164 L60	120.3	108.0	111.9	111.5	116.5	112.7	107.4	102.0	96.2
H164 L70	114.2	102.5	105.5	105.8	110.1	107.0	102.5	95.0	86.0
H165 L30	125.5	118.3	119.7	117.8	120.2	114.0	106.8	102.4	97.4
H165 L40	126.5	118.2	121.3	118.0	122.0	113.9	104.5	95.8	94.3
H165 L50	128.8	117.7	121.5	120.2	125.0	119.4	115.6	111.6	107.8
H165 L60	123.2	110.6	114.5	114.2	119.6	115.4	110.8	105.8	99.1
H165 L70	118.1	105.3	108.2	109.1	114.1	111.5	106.8	100.2	94.3
H166 L30	128.9	121.5	121.8	123.8	122.2	117.5	110.2	107.0	106.0
H166 L40	130.1	121.1	124.5	123.1	125.2	118.2	109.2	103.3	104.2
H166 L50	131.8	120.1	124.8	124.1	127.3	122.4	119.3	115.5	111.0
H166 L60	127.0	113.0	117.8	119.3	123.4	118.7	114.3	109.6	102.9
H166 L70	122.2	108.1	112.2	114.4	118.2	115.5	110.6	103.8	96.3
H170 L30	114.9	111.5	106.7	102.1	106.1	104.8	102.9	100.9	93.2
H170 L40	112.8	108.3	106.8	100.6	105.7	102.7	97.7	90.9	84.8
H170 L50	116.7	108.2	107.5	104.4	110.5	109.5	108.5	106.2	98.6
H170 L60	115.8	103.3	103.3	102.4	111.9	110.0	106.2	103.2	96.0
H170 L70	111.5	100.2	99.4	98.6	105.8	107.1	102.6	97.0	88.5
H171 L30	119.7	116.9	111.8	107.3	109.5	108.1	106.3	103.9	98.5
H171 L40	117.2	113.3	111.9	105.1	108.7	105.7	100.7	95.1	94.2
H171 L50	120.2	112.5	111.9	107.6	113.6	112.6	111.8	108.7	102.5
H171 L60	118.6	107.1	107.2	105.7	114.7	112.3	109.2	105.3	99.4
H171 L70	113.0	102.7	102.4	101.3	107.8	109.3	105.4	99.4	90.6
H172 L30	123.2	120.7	115.6	110.9	113.3	110.6	108.7	105.3	99.4
H172 L40	120.8	117.0	115.7	108.3	111.9	108.3	103.5	96.3	94.4
H172 L50	122.8	115.8	114.8	110.7	116.1	114.9	114.0	110.4	104.1
H172 L60	120.6	109.9	110.3	108.3	116.3	114.2	111.3	107.0	101.0
H172 L70	115.6	106.4	104.8	103.7	110.1	110.4	106.9	100.5	91.7

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

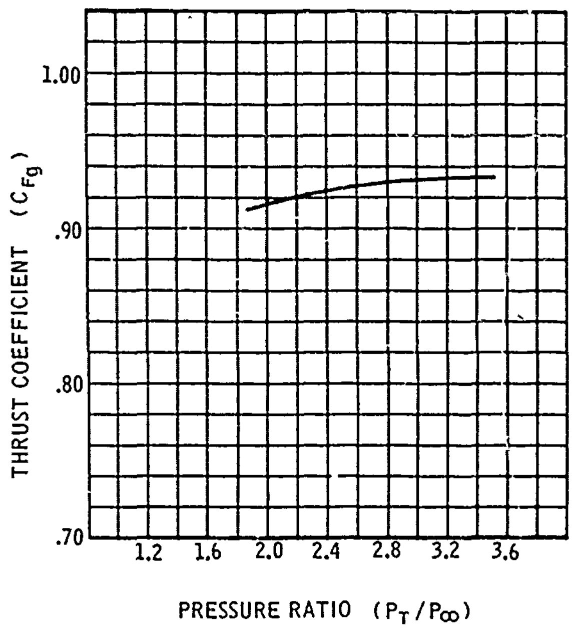
MAE-4A

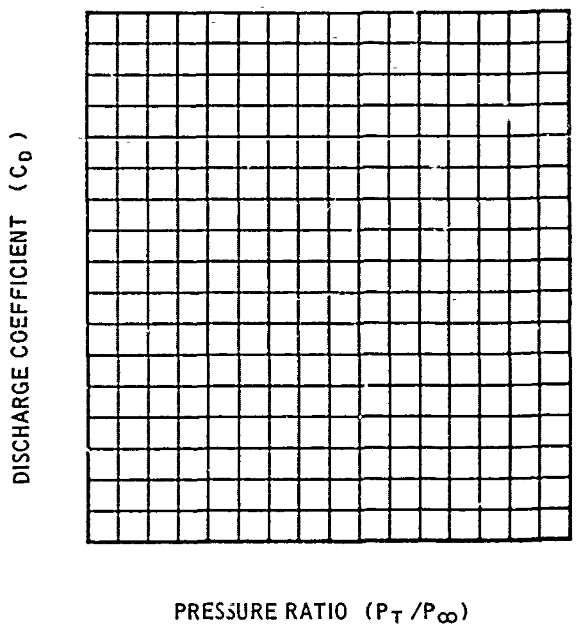
PLUG, 12 WELL VENTILATED SPOKES

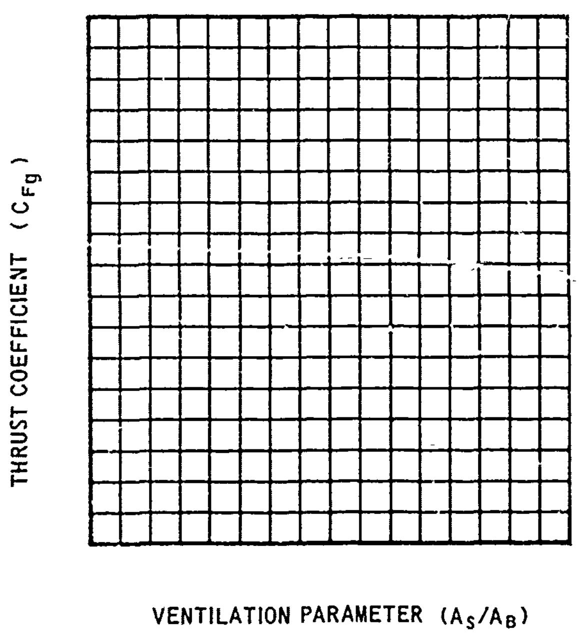


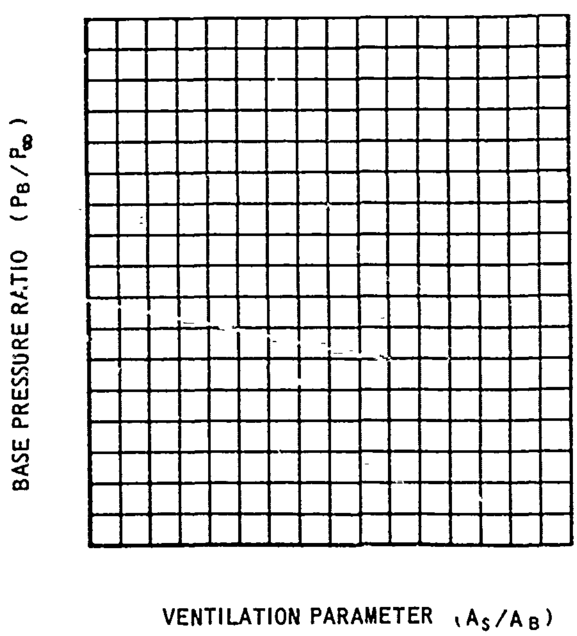
$$C_{Fg} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



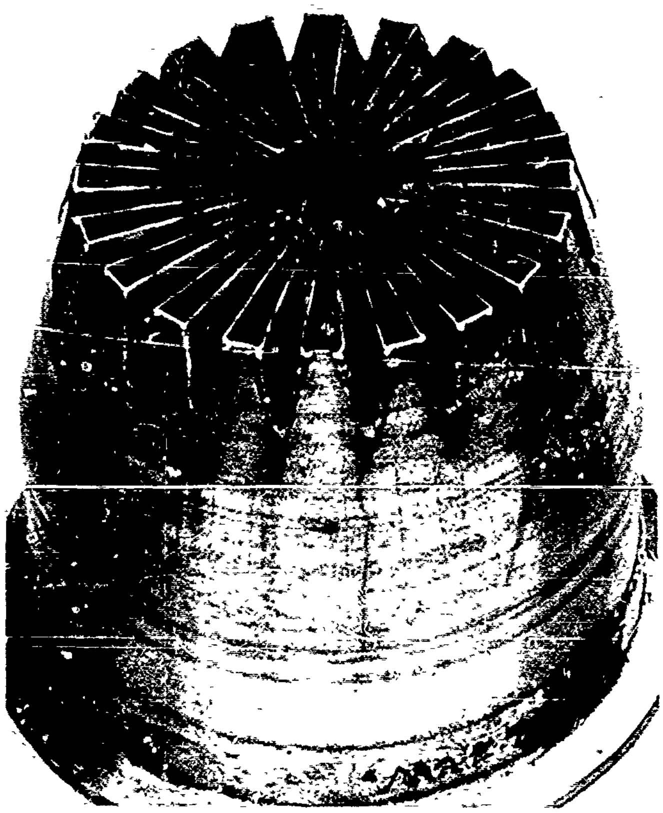






MAE 203-3 NOZZLE

(20 SPOKES, AR 2.2)



Description

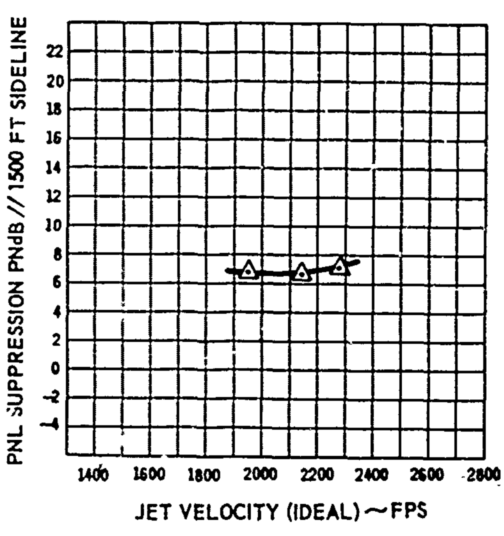
Number of Elements: 30 spokes

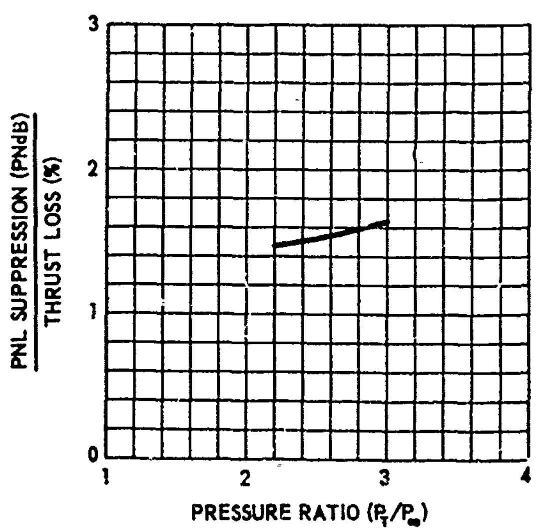
Area Ratio: 2.2

Spoke Penetration: ~ 80%

Flow Area: 3.034 square inches

Exit Cant Angle: 0 degrees

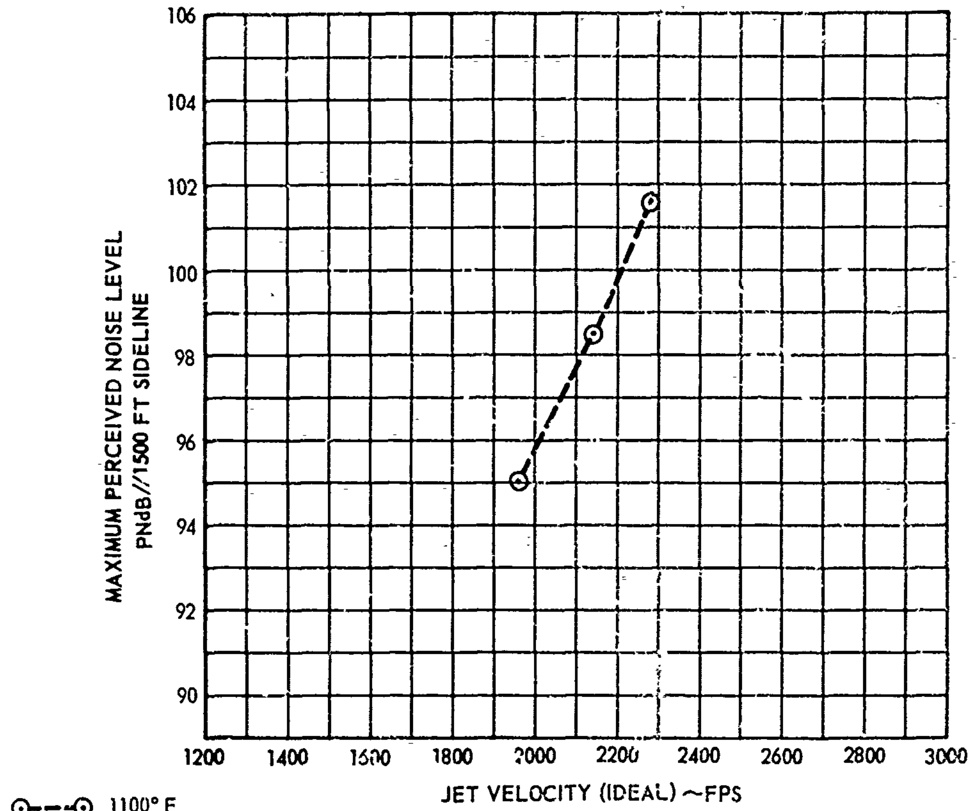




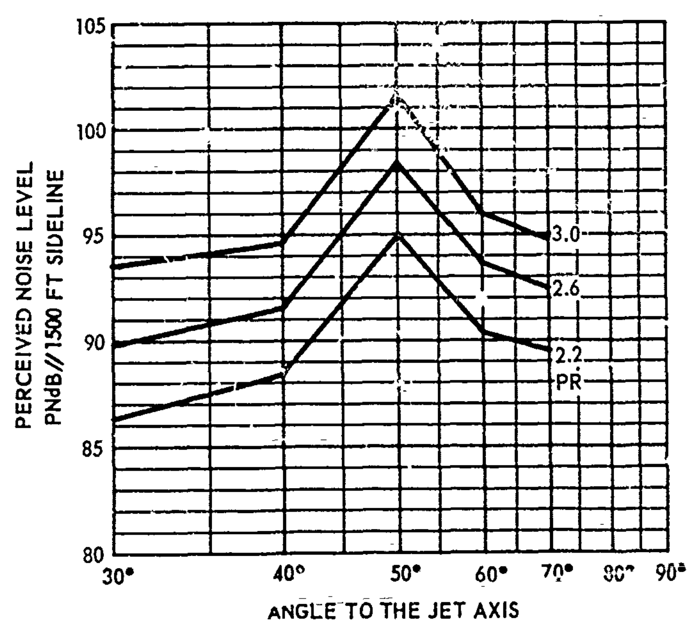
NOZZLE EXIT AREA (A_e): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

MAE 203-3 NOZZLE
(20 SPOKES)
AR 2.2
SCALE FACTOR: 11:1

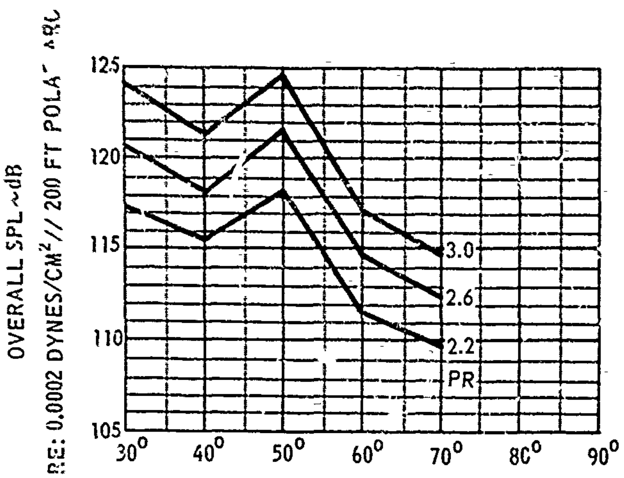


NOZZLE EXIT AREA (A_8): 3.3 FT^2

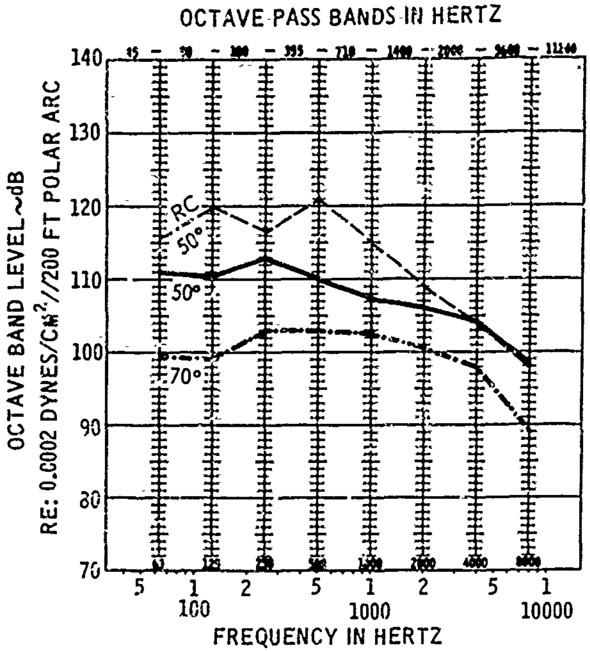


TOTAL TEMPERATURE (T_8): 1100° F
NOZZLE EXIT AREA (A_8): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

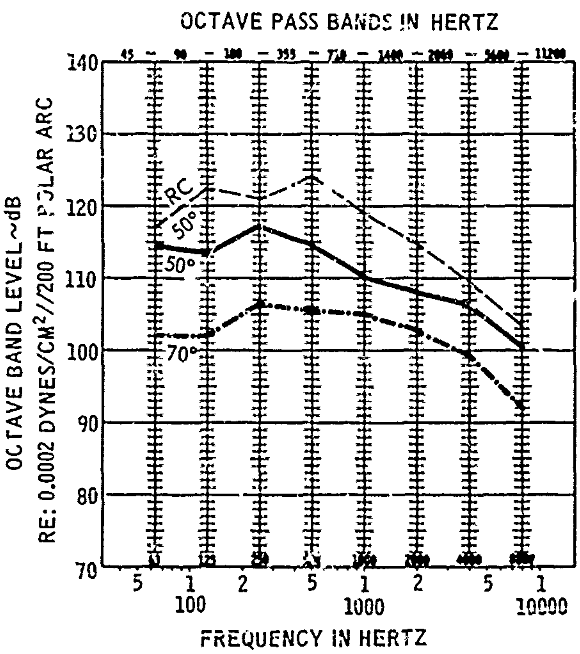


ANGLE TO THE JET AXIS~DEGREES
TOTAL TEMPERATURE (T_8) : 1100° F
NOZZLE EXIT AREA (A_8): 3.3 FT^2

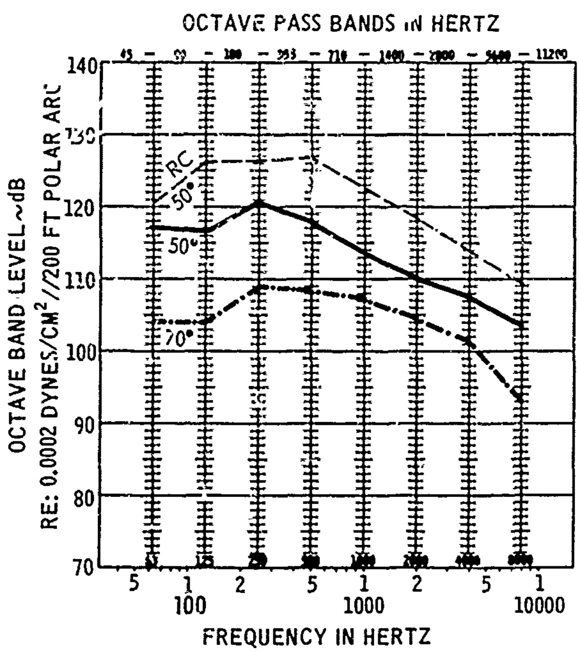


PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1100° F
JET VELOCITY (IDEAL): 1960 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT^2

MAE 203-3 NOZZLE
(20 SPOKES)
AR 2.2
SCALE FACTOR: 11:1



PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1100° F
JET VELOCITY (IDEAL): 2130 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT^2



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1100° F
JET VELOCITY (IDEAL): 2280 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

MAE-203-3

(20 Spokes, AR 2.2)

Remarks

The MAE 203-3 nozzle was fabricated for the 707 airplane jet noise suppression program. The nozzle was retested for the SST program. Jet noise characteristics were reported in Reference D37.

MAE-203-3

Facility: Annex D (Cell #1)
Nozzle and microphone heights are 20 inches.

Date:

T_{amb}:

R. H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H 276	2.2	1100°F	1960 fps	MAE 203-3
H 277	2.6	"	2130	"
H 278	3.0	"	2280	"
H 284	2.2	1100°F	1960 fps	3.08 Inch Round Convergent Nozzle*
H 285	2.6	"	2130	"
H 286	3.0	"	2280	"

* 1/8th scale

Measured acoustic data is recorded in Reference D2.

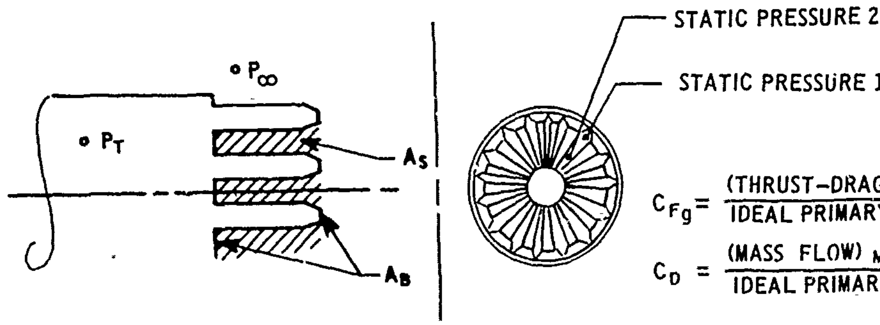
NOZZLE TEST DATA

OCTAVE BAND LEVEL~[illegible] RE: 0.0002 DYNES/CM^2//25 FT

MAE-[illegible]-3

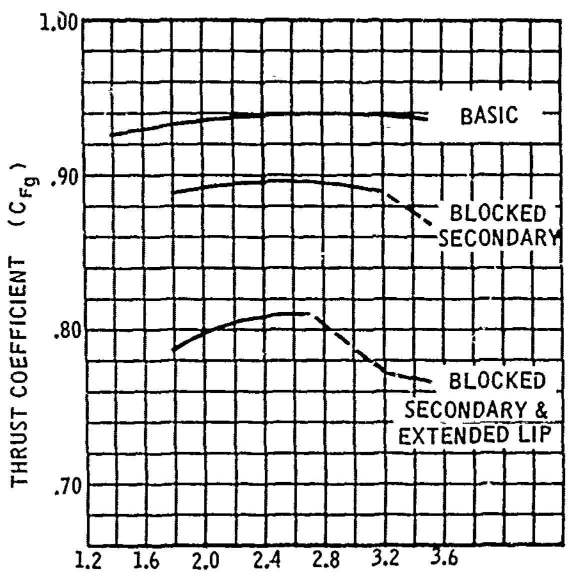
RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H276 L30	117.2	113.5	111.5	108.5	106.5	102.5	101.5	100.0	92.5
H276 L40	115.4	109.5	107.5	106.5	104.5	107.5	105.5	104.5	97.5
H276 L50	118.3	111.0	110.5	[illegible]	110.0	107.5	106.5	104.0	98.5
H276 L60	111.7	102.5	102.0	106.0	105.0	103.0	101.5	98.5	94.0
H276 L70	109.7	99.5	99.0	103.0	103.0	102.5	101.0	98.0	89.0
H277 L30	120.8	116.5	115.5	113.0	110.5	105.5	104.0	102.0	94.5
H277 L40	118.3	118.0	111.0	110.5	108.0	109.0	107.0	106.0	99.5
H277 L50	121.8	114.5	113.5	117.0	114.5	110.0	108.0	106.0	100.5
H277 L60	114.7	105.5	105.0	110.0	108.0	105.0	103.0	100.5	96.0
H277 L70	112.3	102.0	102.0	106.5	105.5	105.0	102.5	99.5	91.0
H278 L30	124.1	119.0	118.5	117.5	115.5	110.0	106.0	103.5	98.0
H278 L40	121.2	115.5	114.0	114.5	111.5	111.5	109.0	107.5	102.5
H278 L50	124.9	117.0	116.5	120.5	118.0	113.5	110.0	107.5	103.5
H278 L60	117.2	107.5	107.5	112.5	111.0	107.5	104.5	102.5	97.0
H278 L70	114.8	104.0	104.0	109.0	108.5	107.5	104.5	101.5	93.0
H284 L30	125.4	116.7	120.3	117.4	120.1	114.7	107.5	103.3	97.2
H284 L40	125.3	115.3	119.7	116.4	121.0	115.3	109.2	104.0	98.2
H284 L50	125.4	114.4	120.0	117.6	120.7	114.8	110.8	104.4	98.0
H284 L60	121.2	109.3	113.9	112.0	117.7	112.7	106.7	101.1	95.8
H284 L70	115.2	103.0	105.9	105.9	110.5	109.3	104.3	98.5	89.7
H285 L30	128.3	119.7	123.6	121.0	121.5	118.0	111.5	107.2	100.7
H285 L40	127.8	118.0	121.8	119.4	123.1	118.4	112.6	108.0	101.9
H285 L50	128.7	117.0	122.8	121.1	123.9	119.3	114.7	109.4	103.4
H285 L60	122.6	110.9	115.4	113.9	118.8	113.9	108.5	103.3	98.1
H285 L70	117.6	104.8	108.3	107.5	113.1	111.6	107.7	102.0	93.9
H286 L30	131.6	122.4	125.2	127.0	124.5	120.6	113.9	110.6	106.5
H286 L40	131.1	120.8	124.9	123.7	126.3	121.6	115.6	111.7	107.7
H286 L50	132.3	120.5	126.2	126.1	126.8	122.7	118.5	113.8	109.5
H286 L60	126.3	113.4	118.3	118.6	122.7	117.1	112.1	107.0	102.3
H286 L70	122.3	108.2	112.4	115.7	116.9	115.9	112.4	106.5	99.4

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

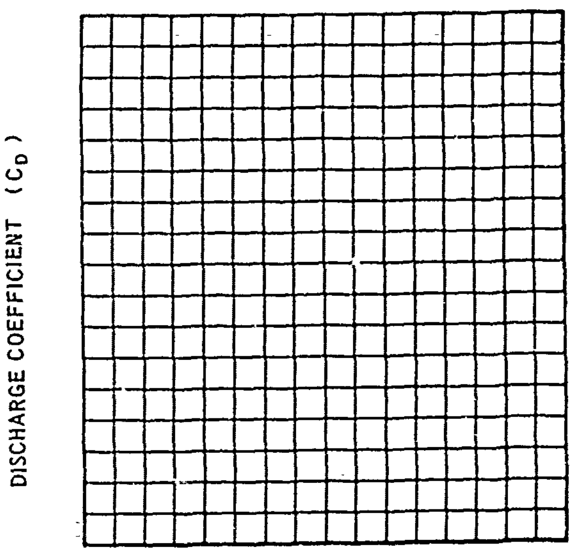


$$C_{Fg} = \frac{\text{(THRUST-DRAG) MEASURED}}{\text{IDEAL PRIMARY THRUST}}$$

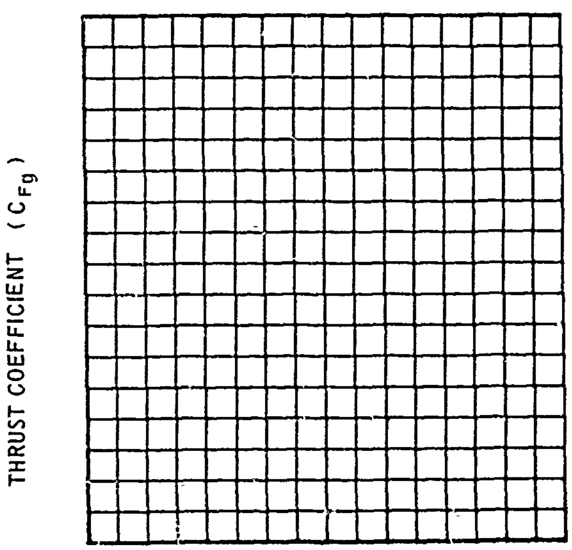
$$C_D = \frac{\text{(MASS FLOW) MEASURED}}{\text{IDEAL PRIMARY MASS FLOW}}$$



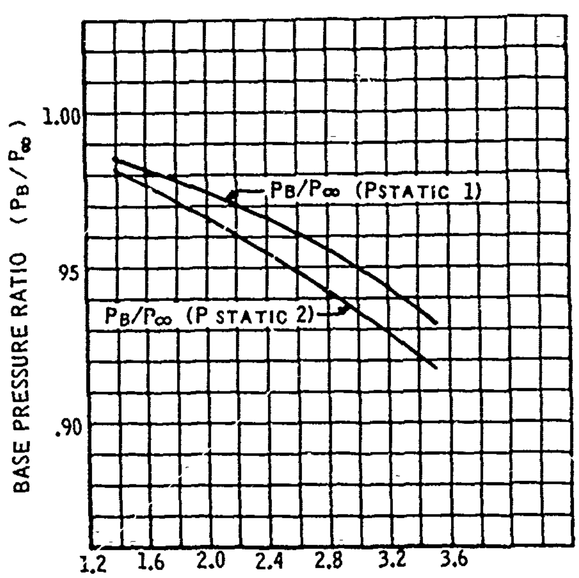
PRESSURE RATIO (P_T/P_∞)



PRESSURE RATIO (P_T/P_∞)



VENTILATION PARAMETER (A_S/A_B)



PRESSURE RATIO (P_T/P_∞)

MPP 130-20 NOZZLE

(16 SPOKES, AR 2.25)

Description

Number of Elements: 16 spokes

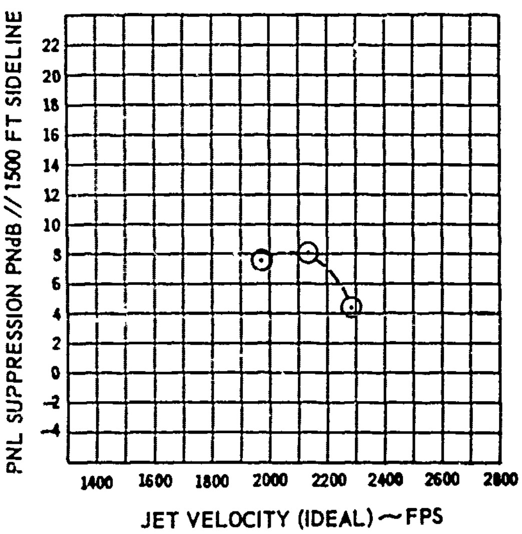
Area Ratio: 2.25

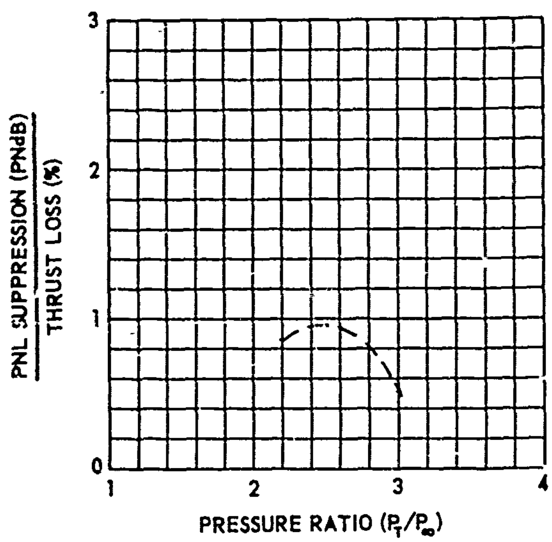
Spoke Penetration: ~ 70%

Flow Area: 5.814 square inches

Exit Cant Angle: 20° (outwards)

NO PICTURE AVAILABLE



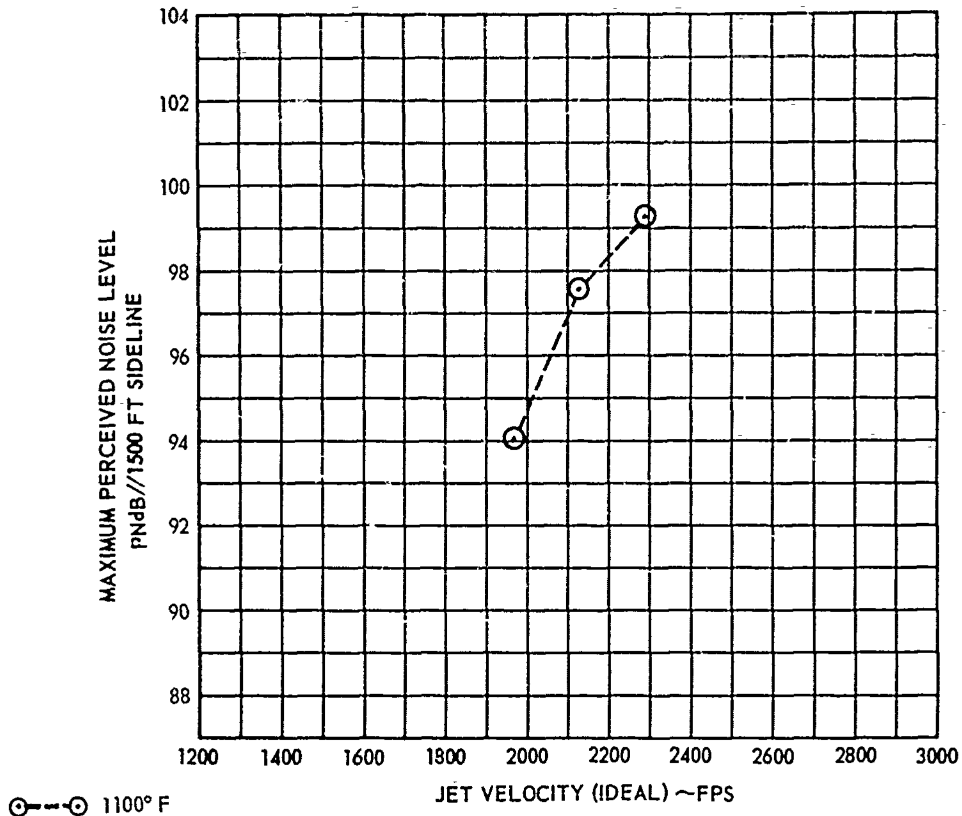


⊙---⊙ 1100° F

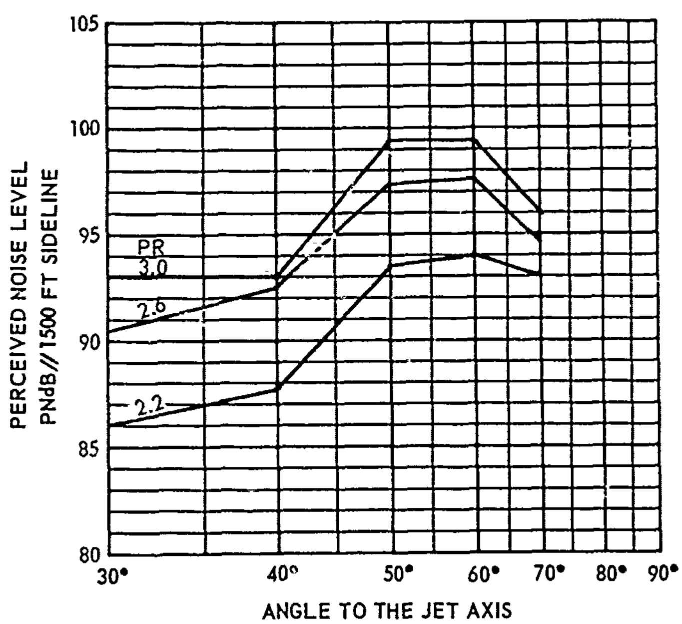
NOZZLE EXIT AREA (A_e): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

MPP 130-20 NOZZLE
(16 SPOKES)
AR 2.25
SCALE FACTOR: 7.4:1

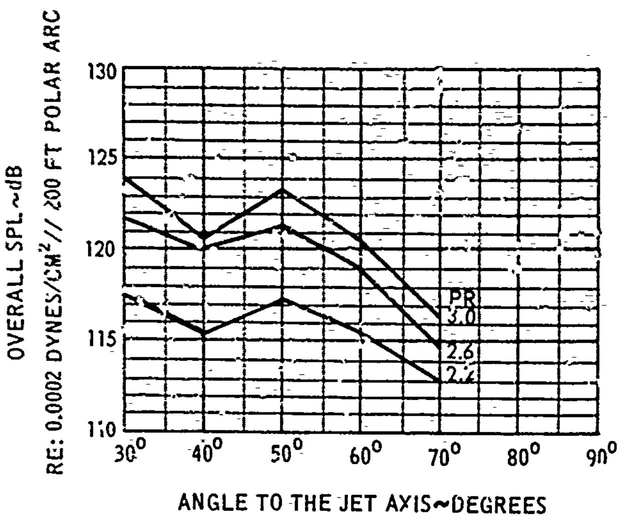


NOZZLE EXIT AREA (A_8): 3.3 FT^2

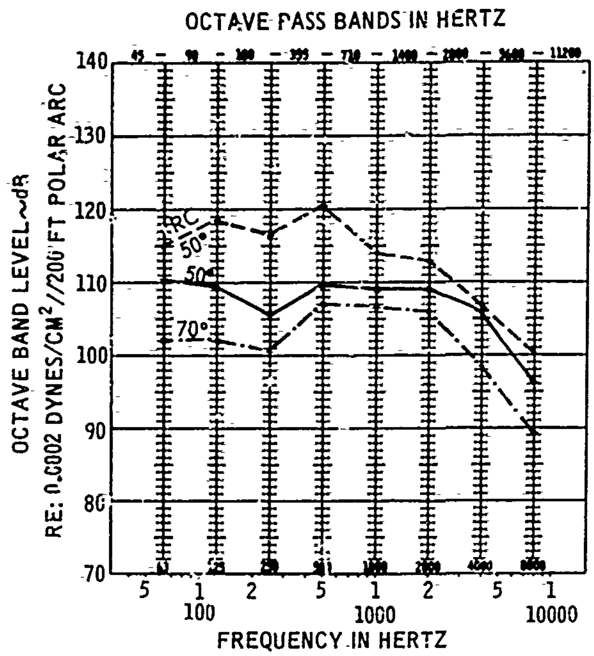


TOTAL TEMPERATURE (T_8): 1100° F
NOZZLE EXIT AREA (A_8): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

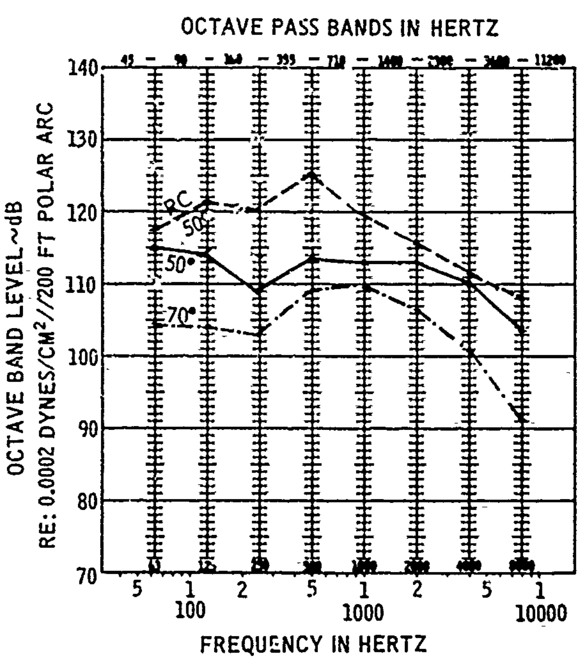


TOTAL TEMPERATURE (T_8) : 1100° F
NOZZLE EXIT AREA (A_8): 3.3 FT²

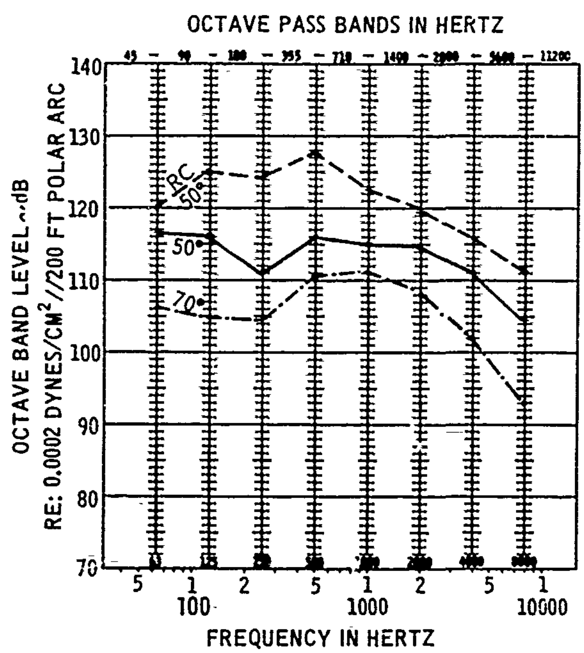


MPP 130-20 NOZZLE
(16 SPOKES)
AR 2.25
SCALE FACTOR: 7.4:1

PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1100° F
JET VELOCITY (IDEAL): 1960 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²



PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1100° F
JET VELOCITY (IDEAL): 2130 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1100° F
JET VELOCITY (IDEAL): 2280 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

MPP-130-20

(16 Spokes, AR 2.25)

Remarks

The MPP 130-20 nozzle was fabricated for the 707 airplane jet noise suppression program. The nozzle was retested for the SST program. Jet noise characteristics were reported in Reference D37.

MPP-130-20

Facility: Annex D (Cell #1)
Nozzle and Microphone Heights are 20 Inches

Date:

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H 176	2.2	1100°F	1960 fps	MPP 130-20
H 177	2.6	"	2130	"
H 178	3.0	"	2280	"
H 164	2.2	1100°F	1960 fps	3.08-In. Round Convergent Nozzle*
H 165	2.6	"	2130	"
H 166	3.0	"	2280	"

* 1/8th scale C-6

Measured acoustic data is recorded in Reference D2.

NOZZLE TEST DATA

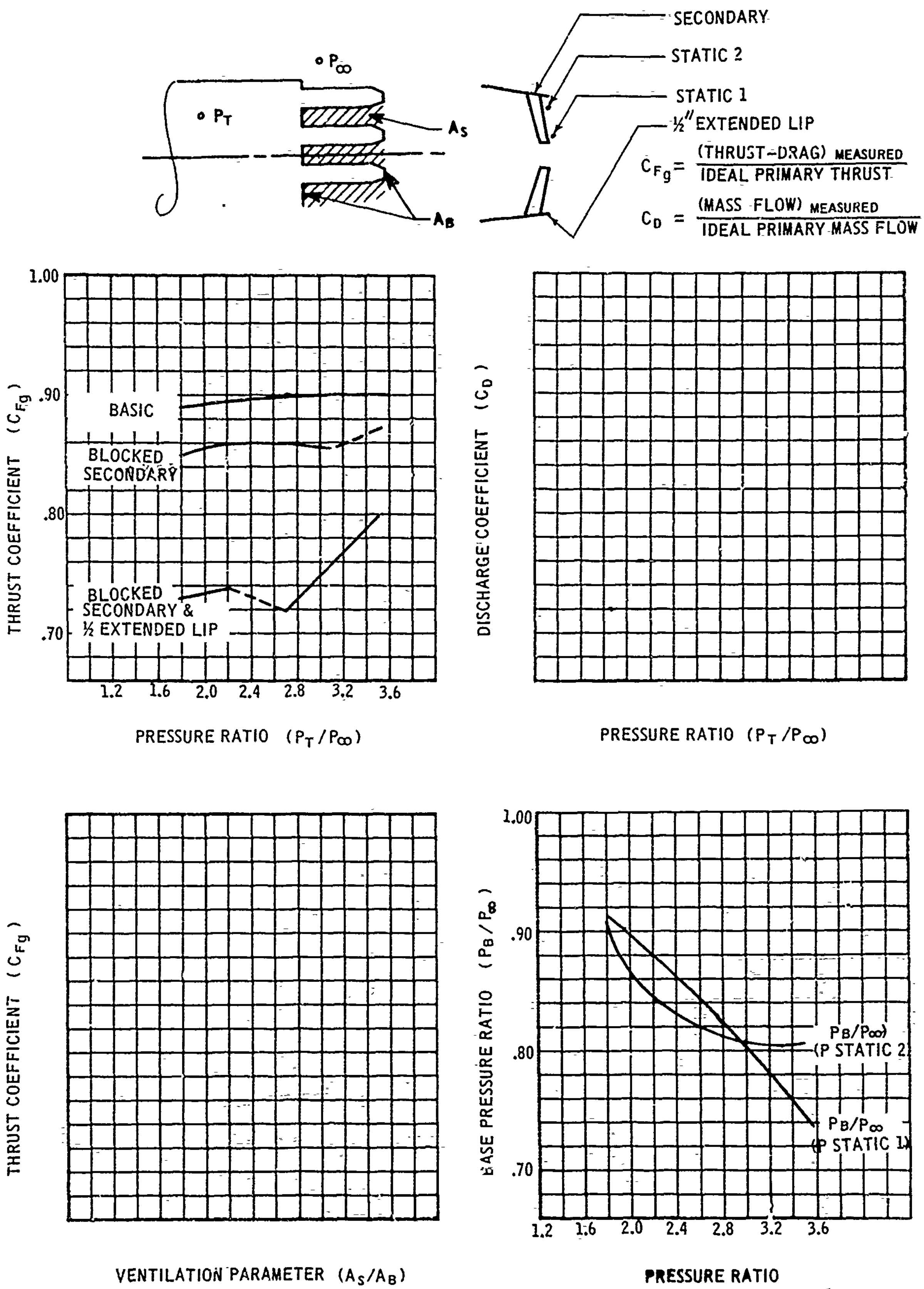
MPP-130-20

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

RUN NO.	OASPL	300	1K	2K	4K	8K	16K	32K	64K
H176 L30	117.4	114.4	110.8	108.9	105.1	106.1	105.1	102.0	94.0
H176 L40	115.3	111.6	110.3	102.4	105.0	103.7	100.5	92.8	85.6
H176 L50	117.3	110.5	109.6	105.4	109.4	109.2	109.1	106.2	96.3
H176 L60	115.3	105.1	105.4	103.8	109.9	109.0	106.7	103.1	96.0
H176 L70	112.9	102.1	102.1	100.5	106.8	107.6	105.8	98.6	89.5
H177 130	121.7	118.5	115.6	108.5	109.3	111.1	108.7	105.0	99.1
H177 L40	119.9	115.8	115.4	106.9	109.2	108.8	105.2	98.8	95.0
H177 L50	121.3	114.0	113.9	109.1	113.5	113.0	112.8	109.7	103.5
H177 L60	118.8	108.8	109.1	107.2	113.6	112.4	110.0	106.1	100.2
H177 L70	114.7	104.6	104.4	102.8	108.7	109.5	106.5	100.6	91.2
H178 L30	124.1	120.8	118.6	111.6	111.9	113.4	109.9	105.7	99.6
H178 L40	120.6	116.6	116.4	108.1	109.3	108.6	103.3	96.5	94.7
H178 L50	123.3	116.7	116.1	111.2	115.9	115.1	114.5	110.9	104.6
H178 L60	120.5	111.0	111.2	108.7	115.4	114.0	111.3	107.3	101.0
H178 L70	116.3	106.0	105.8	104.4	110.5	111.1	107.8	102.0	92.8
H164 L30	125.9	117.6	120.3	117.5	121.2	114.7	108.3	104.2	98.7
H164 L40	123.9	115.9	118.8	115.6	119.0	110.6	100.8	93.2	94.1
H164 L50	124.9	115.0	118.4	116.7	120.4	114.2	113.1	106.3	99.8
H164 L60	120.3	108.0	111.9	111.5	116.5	112.7	107.4	102.0	96.2
H164 L70	114.2	102.5	105.5	105.8	110.1	107.0	102.5	95.0	86.0
H165 L30	125.5	118.3	119.7	117.8	120.2	114.0	106.8	102.4	97.4
H165 L40	126.5	118.2	121.3	118.0	122.0	113.9	104.5	95.8	94.3
H165 L50	128.8	117.7	121.5	120.2	125.0	119.4	115.6	111.6	107.8
H165 L60	123.2	110.6	114.5	114.2	119.6	115.4	110.8	105.8	99.1
H165 L70	118.1	105.3	108.2	109.1	114.1	111.5	106.8	100.2	94.3
H166 L30	128.9	121.5	121.8	123.8	122.2	117.5	110.2	107.0	106.0
H166 L40	130.1	121.1	124.5	123.1	125.2	118.2	109.2	103.3	104.2
H166 L50	131.6	120.1	124.8	124.1	127.3	122.4	119.3	115.5	111.0
H166 L60	127.0	113.0	117.8	119.3	123.4	118.7	114.3	109.6	102.9
H166 L70	122.2	108.3	112.2	114.4	118.2	115.5	110.6	103.8	96.3

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

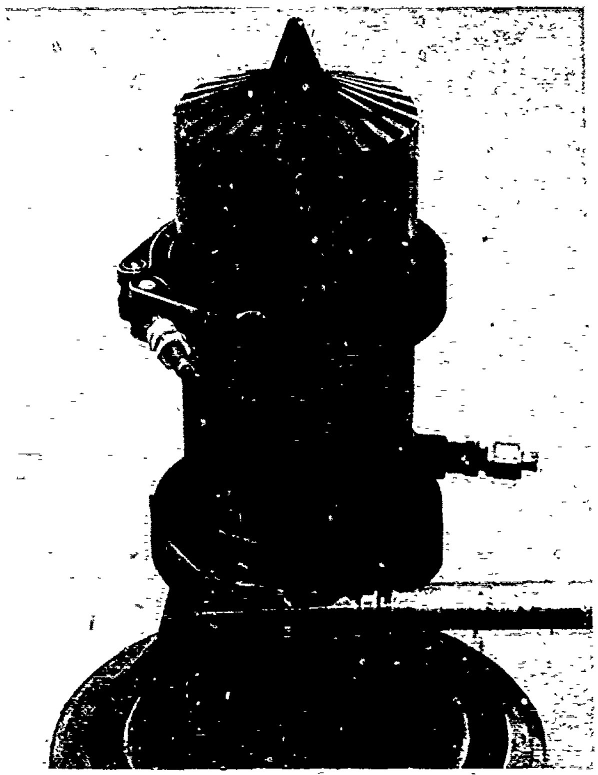
MPP-130-20



SECONDARY
STATIC 2
STATIC 1
½" EXTENDED LIP
P_∞
P_T
A_S
A_B
$C_{Fg} = \frac{(\text{THRUST-DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$
$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$
THRUST COEFFICIENT (C_{Fg})
1.00
.90
.80
.70
BASIC
BLOCKED SECONDARY
BLOCKED SECONDARY & ½ EXTENDED LIP
1.2 1.6 2.0 2.4 2.8 3.2 3.6
PRESSURE RATIO (P_T/P_∞)
DISCHARGE COEFFICIENT (C_D)
PRESSURE RATIO (P_T/P_∞)
THRUST COEFFICIENT (C_{Fg})
VENTILATION PARAMETER (A_S/A_B)
BASE PRESSURE RATIO (P_B/P_∞)
1.00
.90
.80
.70
P_B/P_∞ (P STATIC 2)
P_B/P_∞ (P STATIC 1)
1.2 1.6 2.0 2.4 2.8 3.2 3.6
PRESSURE RATIO

MAE 53-18 NOZZLE

(24 SPOKE AND CENTER PLUG, AR 2.1)



Description:

Number of Elements: 24 spokes and conical center plug

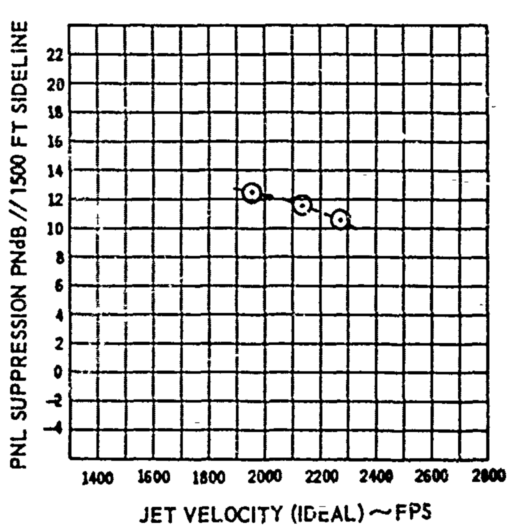
Area Ratio: 2.1

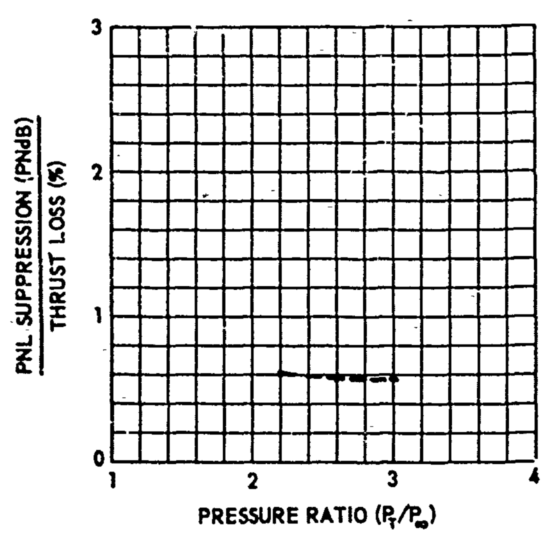
Spoke Penetration: ~ 80%, terminatine at center plug

Flow Area: 5.94 square inches

Exit Cant Angle: 18° outward

Ventilation Cant Angle: 18°



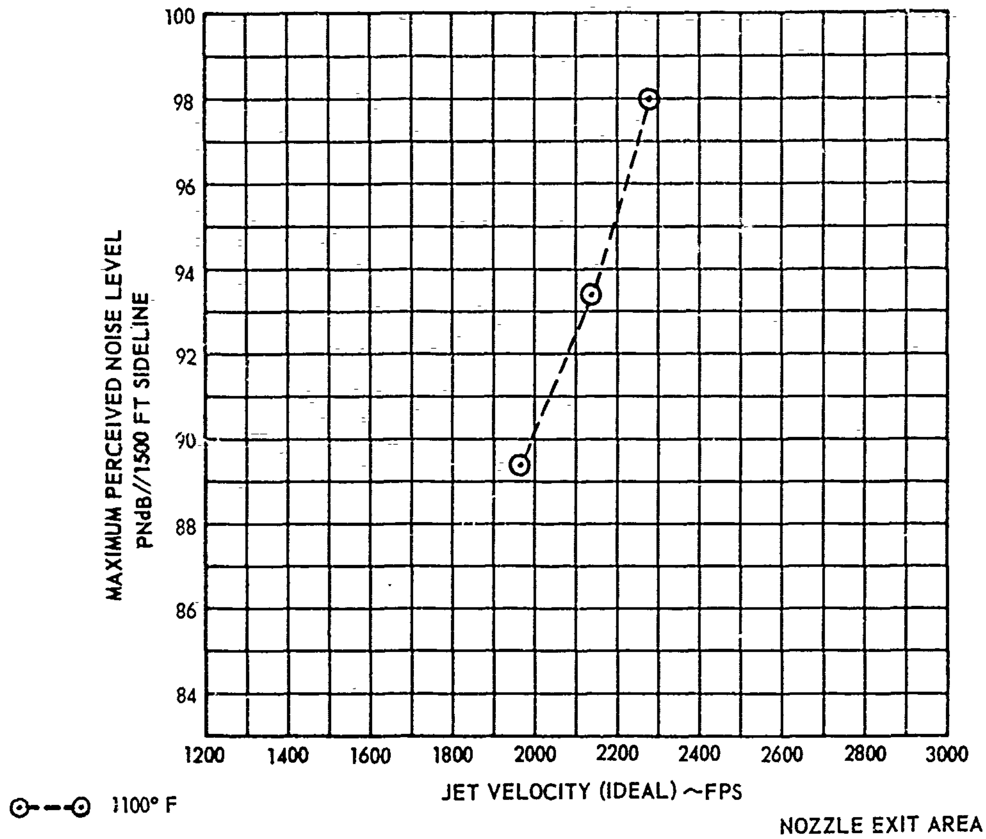


⊙—⊙ 1100° F

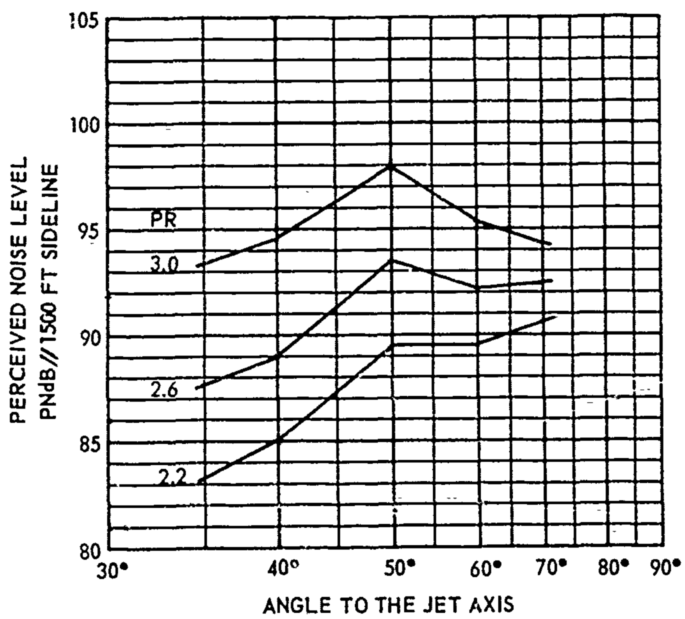
NOZZLE EXIT AREA (A_e): 3.3 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

MAE 53-18 NOZZLE
(24 SPOKES AND CENTER PLUG)
AR 2.1
SCALE FACTOR: 8:1

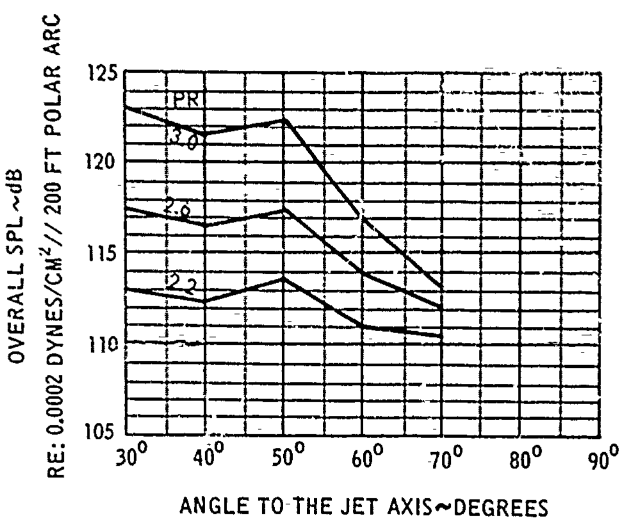


NOZZLE EXIT AREA (A_8): 3.3 FT^2



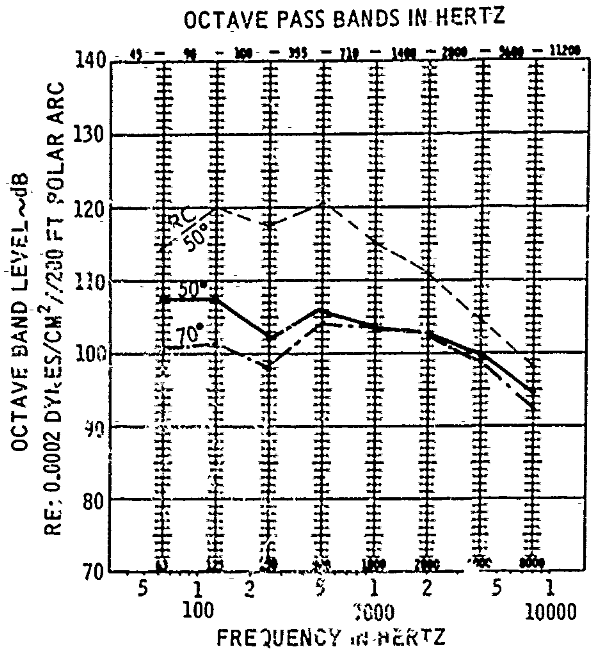
TOTAL TEMPERATURE (T_8): 1100° F
NOZZLE EXIT AREA (A_8): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

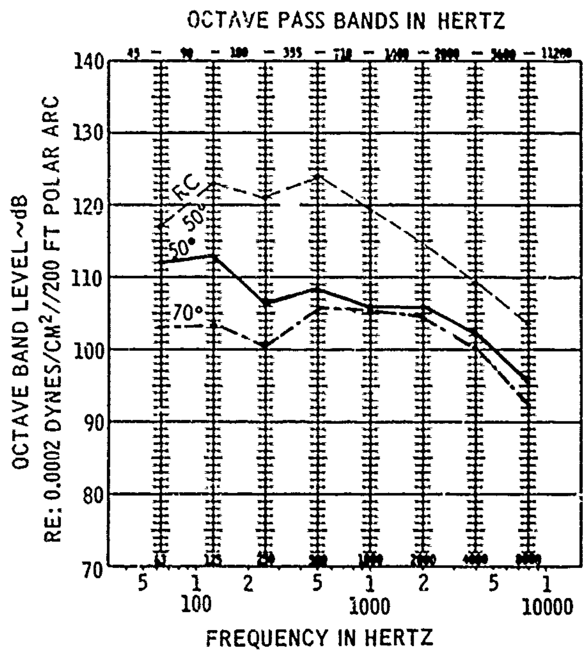


TOTAL TEMPERATURE (T_8) : 1100° F
NOZZLE EXIT AREA (A_8): 3.3 FT²

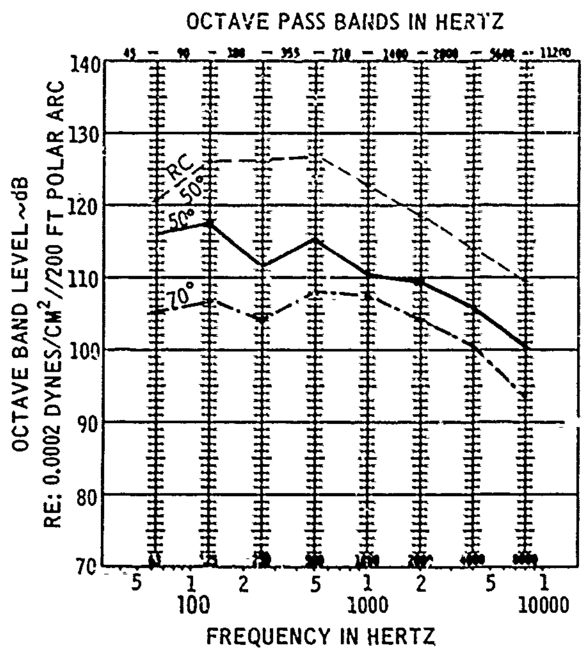
MAE 53-18 NOZZLE
(24 SPOKES AND CENTER PLUG)
AR 2.1
SCALE FACTOR: 8:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1100° F
JET VELOCITY (IDEAL): 1960 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²



PRESSURE RATIO: 2.6
TOTAL TEMPERATURE: 1100° F
JET VELOCITY (IDEAL): 2130 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1100° F
JET VELOCITY (IDEAL): 2280 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

MAE-53-18

(24 Spokes and Center Plug, AR 2.1)

Remarks

The MAE 53-18 nozzle was fabricated for the 707 airplane jet noise suppression program. The nozzle was retested for the SST program. Jet noise characteristics were reported in Reference D37. Tests with the MAE 53-18 nozzle with the center plug removed yielded about the same PNL suppression values. With the plug removed an increase in low frequency noise (octave bands 1 and 2) was noted, e.g., 8 dB increase at 50° relative to the jet axis, PR = 3.0 and T_T = 1100°F.

Facility: Annex D (Cell #1)
Nozzle and Microphone Heights are 20 Inches

Date:

T_{amb}:

R.H.:

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
H 281	2.2	1100°F	1960 fps	MAE 53-18
H 282	2.6	"	2130	"
H 283	3.0	"	2280	"
H 284	2.2	1100°F	1960 fps	3.08-In. Round Convergent Nozzle*
H 285	2.6	"	2130	"
H 286	3.0	"	2280	"

*1/8th scale C-6

Measured acoustic data is recorded in Reference D2.

NOZZLE TEST DATA

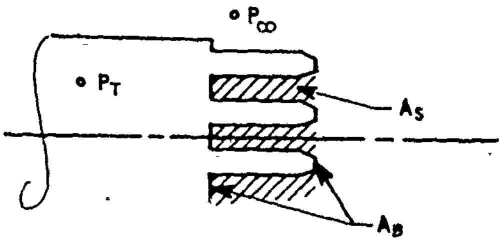
OCTAVE BAND LEVEL—dB RE: 0.0002 DYNES/CM²//25 FT

MAE 53–18

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
H281L30	113.0	110.3	107.1	99.0	101.0	99.9	98.6	96.6	89.0
H281L40	112.3	108.2	107.2	99.0	102.3	100.9	99.8	97.0	90.5
H281L50	113.6	107.7	107.8	102.0	105.3	103.5	102.8	100.6	94.7
H281L60	111.0	103.0	103.9	99.8	105.3	102.7	100.6	97.6	92.7
H281L70	110.4	100.5	101.3	97.8	104.0	103.6	103.2	99.3	92.2
H282L30	117.5	115.1	110.9	104.8	105.5	103.6	101.3	98.6	90.5
H282L40	116.4	112.5	111.7	103.1	106.0	103.0	102.1	99.5	91.9
H282L50	117.4	111.7	112.8	106.5	108.6	106.0	105.9	102.5	95.8
H282L60	113.8	106.4	107.4	103.0	108.4	104.3	101.2	99.5	94.0
H282L70	112.2	103.0	103.7	100.5	105.6	105.6	104.3	100.2	92.5
H283L30	122.9	119.2	118.0	111.4	113.8	108.0	103.7	100.5	95.3
H283L40	121.6	116.8	117.4	109.1	113.2	108.5	105.5	102.3	97.0
H283L50	122.3	115.9	117.6	111.7	115.3	110.6	109.4	105.8	100.2
H283L60	117.0	109.5	111.0	106.7	111.8	107.0	103.2	100.6	95.8
H283L70	114.2	105.3	106.7	103.8	108.1	107.4	104.4	100.6	93.6
H284L30	125.4	116.7	120.3	117.4	120.1	114.7	107.5	103.3	97.2
H284L40	125.3	115.3	119.7	116.4	121.0	115.3	109.2	104.0	98.2
H284L50	125.4	114.4	120.0	117.6	120.7	114.8	110.8	104.4	98.0
H284L60	121.2	108.3	113.9	112.0	117.7	112.7	106.7	101.1	95.8
H284L70	115.2	103.0	105.9	105.9	110.5	109.3	104.3	98.5	89.7
H295L30	128.3	119.7	123.6	121.0	121.5	118.0	111.5	107.2	100.7
H285L40	127.8	118.0	121.8	119.4	123.1	118.4	112.6	108.0	101.9
H285L50	128.7	117.0	122.8	121.1	123.9	119.3	114.7	109.4	103.4
H285L60	122.6	110.9	115.4	113.9	118.8	113.9	108.5	103.3	98.1
H285L70	117.6	104.8	108.3	107.5	113.1	111.6	107.7	102.0	93.9
H286L30	131.6	122.4	125.2	127.0	124.5	120.6	113.9	110.6	106.5
H286L40	131.1	120.8	124.9	123.7	126.3	121.6	115.6	111.7	107.7
H286L50	132.3	120.8	126.2	126.1	126.8	122.7	118.5	113.8	109.5
H286L60	126.3	113.4	118.3	118.6	122.7	117.1	112.1	107.0	102.3
H286L70	122.3	108.2	112.4	115.7	116.9	115.9	112.4	106.5	99.4

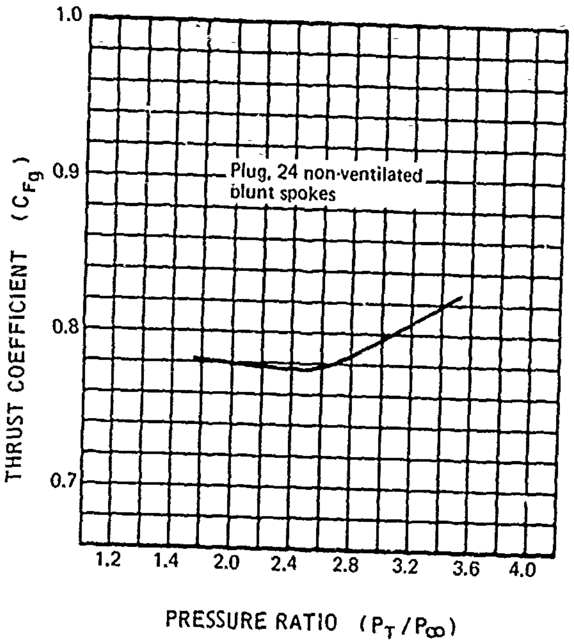
NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

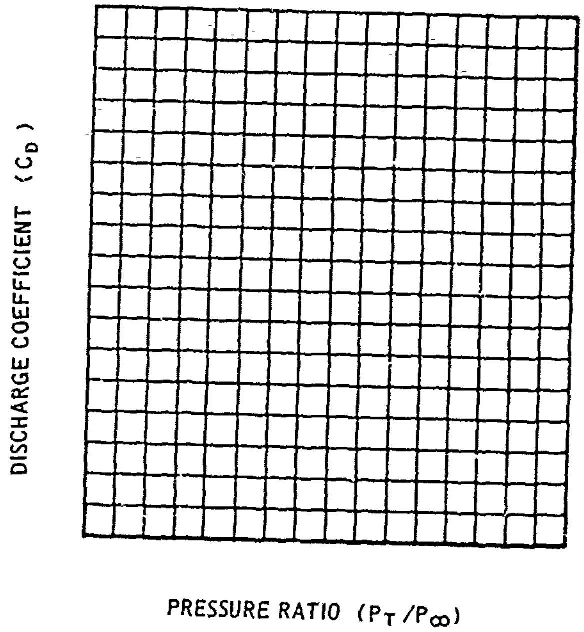
MAE-53-18

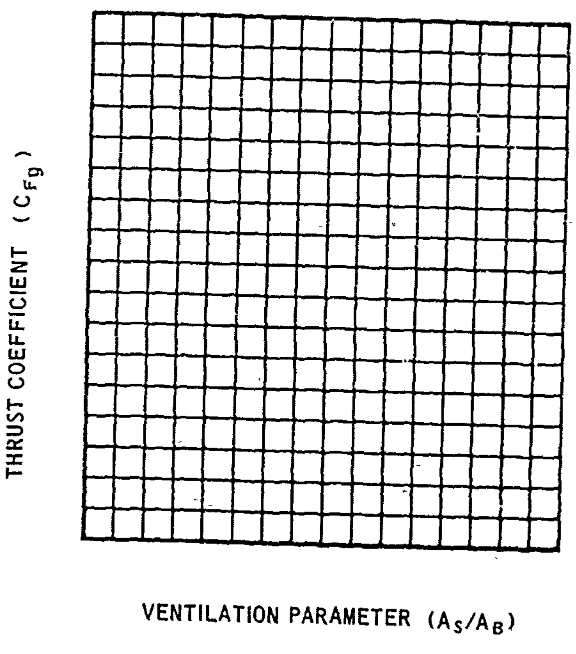


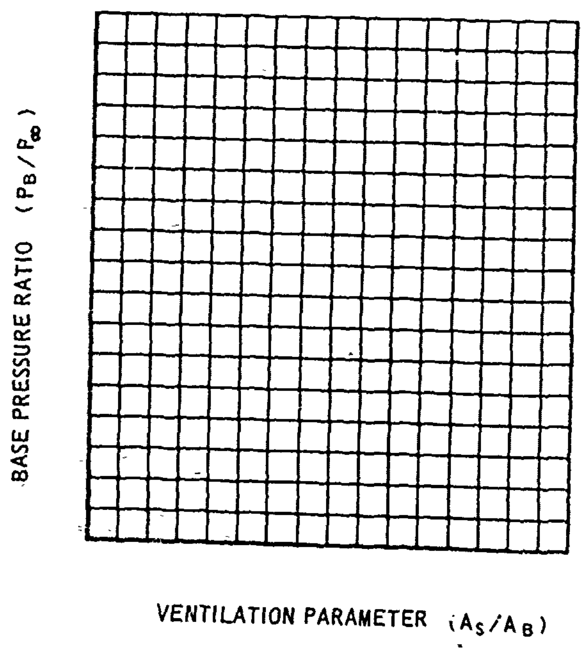
$$C_{Fg} = \frac{(\text{THRUST–DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



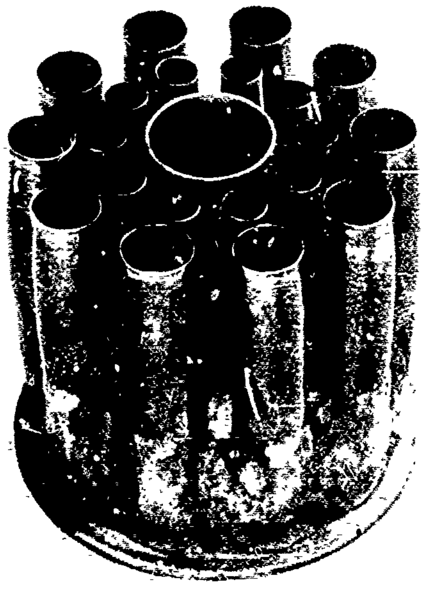






MPP 152 NOZZLE

(21 TUBES, AR 2.4)



Description:

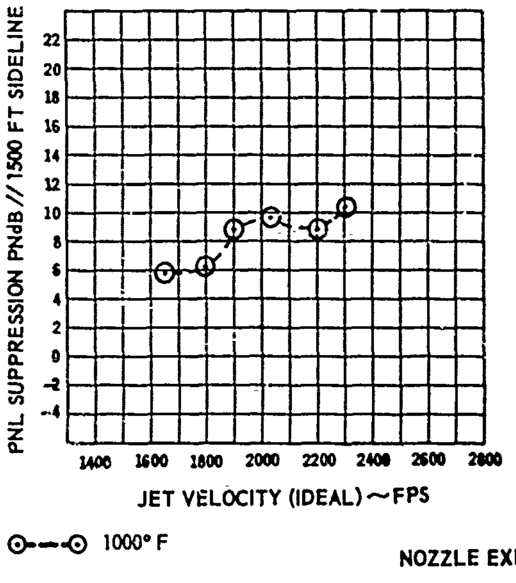
The MMP 152 nozzle is a well-ventilated 21 tube nozzle. There are 10 tubes in the outer row, 10 smaller tubes in the inner row, and one relatively large tube in the center.

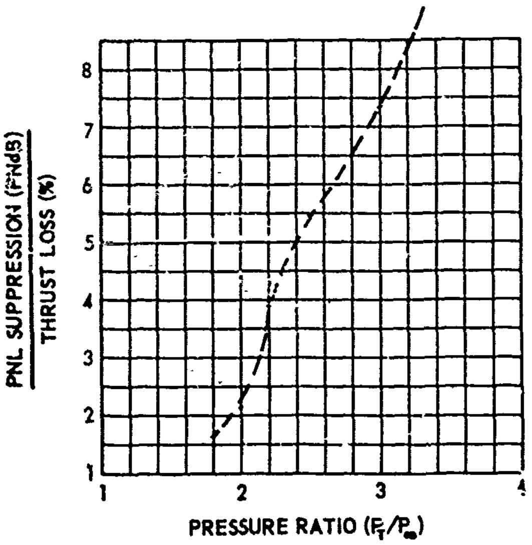
Number of Elements: 21 round convergent tubes (3 sizes)

Area Ratio: 2.4

Flow Area: 6.48 square inches

Exit Cant Angle: 0 degrees

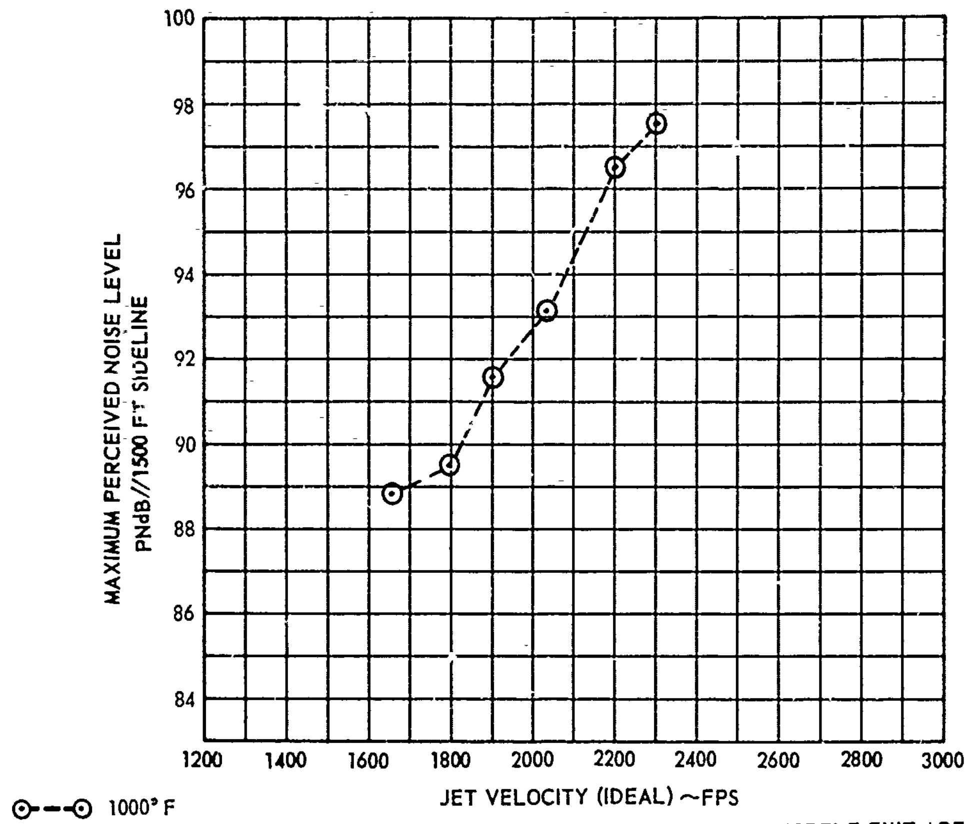




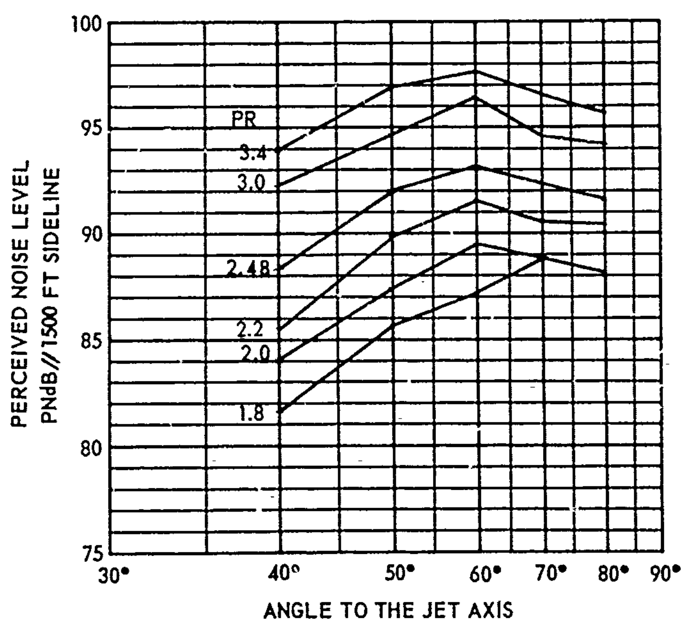
NOZZLE EXIT AREA (A_e): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

MPP 152 NOZZLE
(21 TUBES)
AR 2.4
SCALE FACTOR: 7.7:1



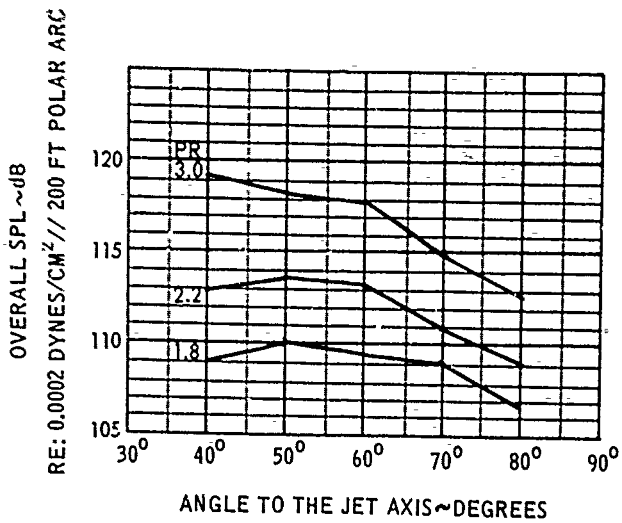
NOZZLE EXIT AREA (A_8): 3.3 FT^2



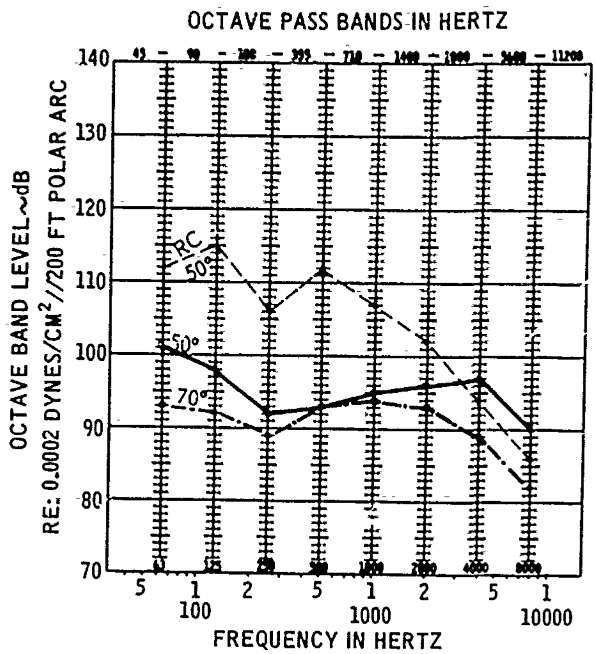
TOTAL TEMPERATURE (T_8): 1000° F

NOZZLE EXIT AREA (A_8): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

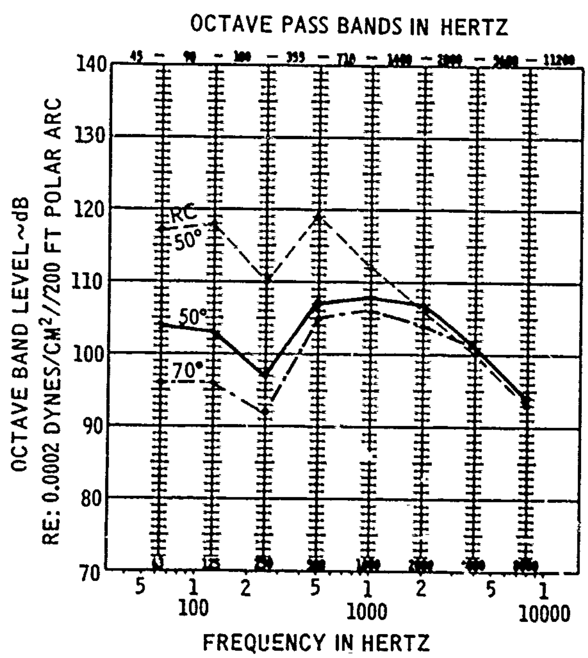


TOTAL TEMPERATURE (T_8): 1000° F
NOZZLE EXIT AREA (A_8): 3.3 FT²

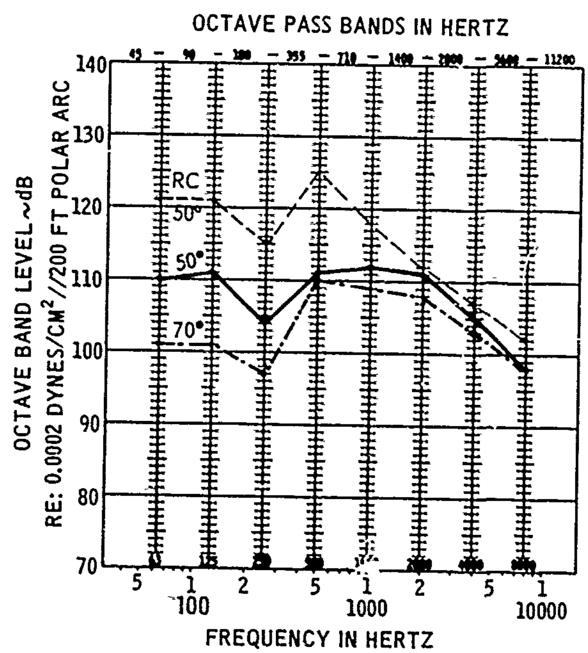


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1000° F
JET VELOCITY (IDEAL): 1659 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²

MPP 152 NOZZLE
(21 TUBES)
AR 2.4
SCALE FACTOR: 7.7:1



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1000° F
JET VELOCITY (IDEAL): 1900 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1000° F
JET VELOCITY (IDEAL): 2205 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

Facility: Annex D (Cell #1)
Nozzle and Microphone Height are 20 Inches

Date: February 8, 1968

T_{amb}: 51°F

R.H.: 69%

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
2288	1.8	1000°F	1659 fps	MPP 152
2289	2.0	"	1790	"
2290	2.2	"	1900	"
2291	2.48	"	2030	"
2292	3.0	"	2205	"
2293	3.4	"	2311	"
2306	1.8	1000°F	1659 fps	3.08 Inch Round Convergent
2307	2.0	"	1790	"
2308	2.2	"	1900	"
2309	2.48	"	2030	"
2310	3.0	"	2205	"
2311	3.4	"	2311	"

MPP 152

(21 Tubes, AR 2.4)

Remarks

The MPP 152 nozzle was fabricated for the 707 airplane jet noise suppression program. It is similar to the 21 tube suppressor nozzle that was eventually installed on the JT-3/C-6 trubojet engines. The nozzle was retested for the SST program. Jet noise characteristics were reported in References D37 and D38.

NOZZLE TEST DATA

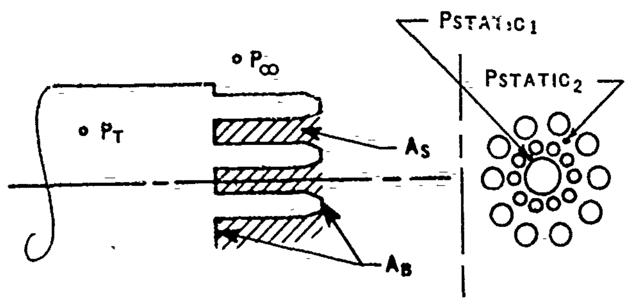
OCTAVE BAND LEVEL—dB RE: 0.0002 DYNES/CM^2//25 FT

MPP-152

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
2288 L40	109.1	102.0	99.0	91.0	102.0	103.0	102.0	96.0	89.0
2288 L50	109.9	101.0	98.0	92.0	103.0	105.0	103.0	97.0	90.0
2288 L60	109.5	96.0	95.0	92.0	102.0	106.0	102.0	98.0	92.0
2288 L70	109.0	93.0	92.0	89.0	103.0	104.0	103.0	99.0	92.0
2288 L80	106.7	91.0	90.0	89.0	97.0	102.0	102.0	98.0	90.0
2289 L40	111.0	104.0	102.0	94.0	104.0	104.0	104.0	98.0	92.0
2289 L50	111.7	104.0	101.0	94.0	105.0	106.0	104.0	99.0	92.0
2289 L60	111.1	97.0	97.0	94.0	105.0	106.0	105.0	100.0	93.0
2289 L70	109.1	94.0	94.0	90.0	103.0	104.0	103.0	99.0	93.0
2289 L80	106.9	92.0	92.0	90.0	101.0	101.0	101.0	98.0	91.0
2290 L40	112.8	106.0	105.0	96.0	105.0	106.0	105.0	100.0	94.0
2290 L50	113.6	104.0	103.0	97.0	107.0	108.0	107.0	101.0	94.0
2290 L60	113.3	100.0	99.0	96.0	108.0	108.0	107.0	101.0	95.0
2290 L70	110.8	96.0	96.0	92.0	105.0	106.0	104.0	101.0	94.0
90 L80	109.2	94.0	94.0	93.0	104.0	103.0	103.0	100.0	93.0
91 L40	115.4	109.0	108.0	99.0	108.0	108.0	107.0	102.0	95.0
91 L50	115.6	107.0	106.0	100.0	109.0	109.0	109.0	103.0	97.0
1 L60	114.9	102.0	102.0	98.0	110.0	109.0	108.0	103.0	97.0
1 L70	112.4	97.0	98.0	94.0	107.0	107.0	106.0	102.0	95.0
91 L80	110.3	96.0	96.0	94.0	105.0	104.0	104.0	101.0	94.0
2292 L40	119.2	113.0	114.0	104.0	111.0	111.0	109.0	103.0	97.0
2292 L50	118.3	110.0	111.0	104.0	110.0	112.0	111.0	105.0	98.0
2292 L60	117.9	105.0	106.0	102.0	113.0	112.0	111.0	106.0	99.0
2292 L70	114.8	101.0	101.0	97.0	110.0	109.0	108.0	103.0	98.0
2292 L80	112.7	98.0	98.0	97.0	107.0	106.0	107.0	104.0	96.0
2293 L40	120.9	115.0	116.0	107.0	113.0	112.0	109.0	104.0	98.0
2293 L50	120.7	112.0	114.0	107.0	114.0	114.0	112.0	107.0	100.0
2293 L60	119.0	107.0	108.0	104.0	114.0	113.0	112.0	106.0	100.0
2293 L70	116.5	102.0	103.0	100.0	112.0	111.0	109.0	105.0	99.0
2293 L80	114.3	100.0	100.0	99.0	109.0	108.0	108.0	105.0	98.0
2306 L40	119.0	112.0	115.0	112.0	111.0	104.0	98.0	90.0	85.0
2306 L50	118.7	112.0	115.0	106.0	112.0	107.0	102.0	94.0	86.0
2306 L60	114.7	107.0	108.0	104.0	110.0	106.0	101.0	94.0	86.0
2306 L70	110.6	101.0	102.0	100.0	105.0	105.0	100.0	93.0	83.0
2306 L80	108.5	98.0	98.0	99.0	104.0	102.0	99.0	92.0	83.0
2307 L40	122.2	114.0	117.0	112.0	118.0	109.0	103.0	96.0	90.0
2307 L50	121.7	114.0	117.0	109.0	117.0	111.0	104.0	97.0	90.0
2307 L60	117.7	109.0	110.0	106.0	114.0	109.0	105.0	97.0	90.0
2307 L70	114.2	104.0	104.0	101.0	111.0	107.0	103.0	96.0	88.0
2307 L80	111.3	100.0	101.0	100.0	108.0	104.0	101.0	94.0	86.0
2308 L40	123.8	115.0	118.0	114.0	120.0	111.0	106.0	99.0	93.0
2308 L50	123.5	117.0	118.0	110.0	119.0	112.0	106.0	100.0	93.0
2308 L60	120.5	110.0	113.0	109.0	117.0	112.0	108.0	102.0	94.0
2308 L70	115.6	104.0	105.0	103.0	112.0	109.0	106.0	99.0	91.0
2308 L80	112.7	100.0	102.0	102.0	109.0	106.0	103.0	97.0	88.0
2309 L40	126.3	117.0	120.0	116.0	123.0	114.0	109.0	102.0	96.0
2309 L50	124.9	119.0	117.0	113.0	121.0	114.0	108.0	102.0	96.0
2309 L60	122.1	114.0	114.0	110.0	118.0	114.0	110.0	105.0	97.0
2309 L70	117.7	107.0	107.0	105.0	116.0	111.0	108.0	102.0	94.0
2309 L80	114.7	101.0	103.0	103.0	110.0	109.0	107.0	101.0	92.0
2310 L40	128.5	119.0	124.0	120.0	123.0	117.0	112.0	107.0	101.0
2310 L50	128.4	121.0	121.0	115.0	125.0	118.0	112.0	107.0	102.0
2310 L60	126.3	115.0	117.0	115.0	123.0	118.0	116.0	110.0	103.0
2310 L70	122.6	109.0	109.0	113.0	119.0	116.0	113.0	107.0	99.0
2310 L80	120.3	104.0	106.0	109.0	116.0	115.0	112.0	106.0	98.0
2311 L40	131.7	125.0	125.0	121.0	128.0	118.0	113.0	107.0	102.0
2311 L50	130.9	121.0	125.0	121.0	125.0	124.0	118.0	113.0	107.0
2311 L60	126.2	117.0	117.0	117.0	120.0	120.0	117.0	111.0	105.0
2311 L70	123.7	109.0	110.0	112.0	117.0	120.0	116.0	110.0	103.0
2311 L80	121.8	105.0	107.0	112.0	115.0	118.0	114.0	109.0	101.0

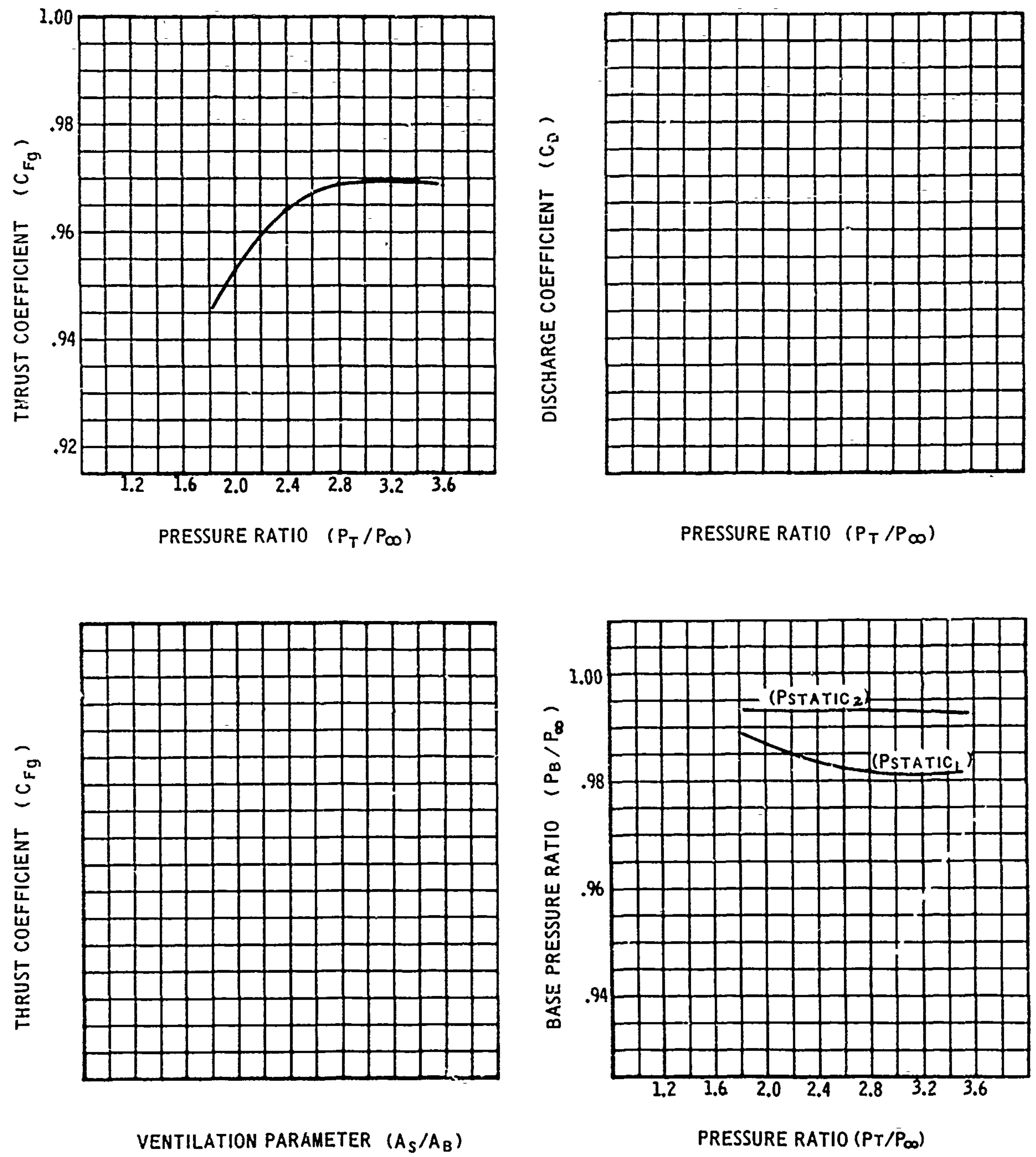
NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

MPP-152 J

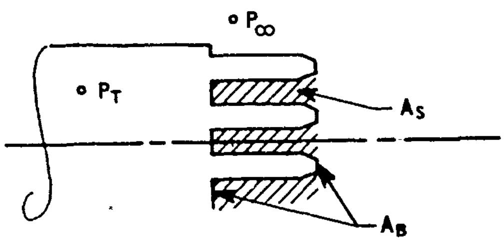


$$C_{Fg} = \frac{(\text{THRUST–DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$

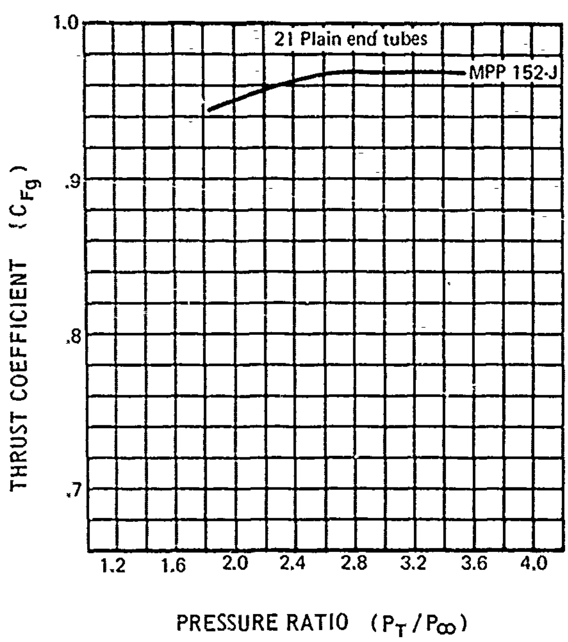


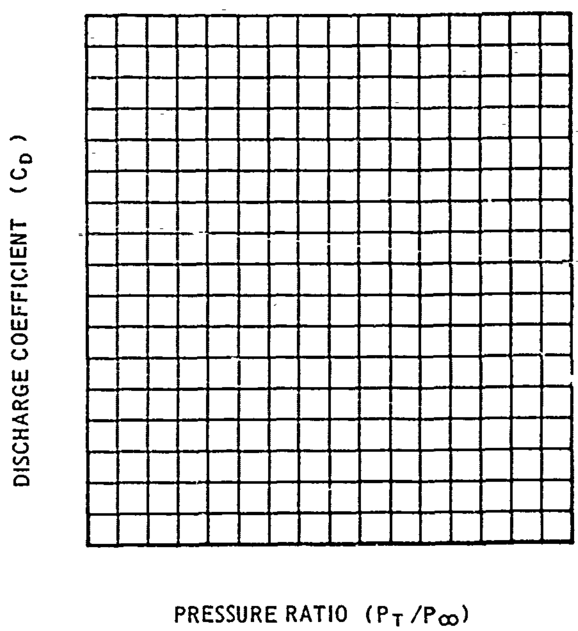
MPP-152-J

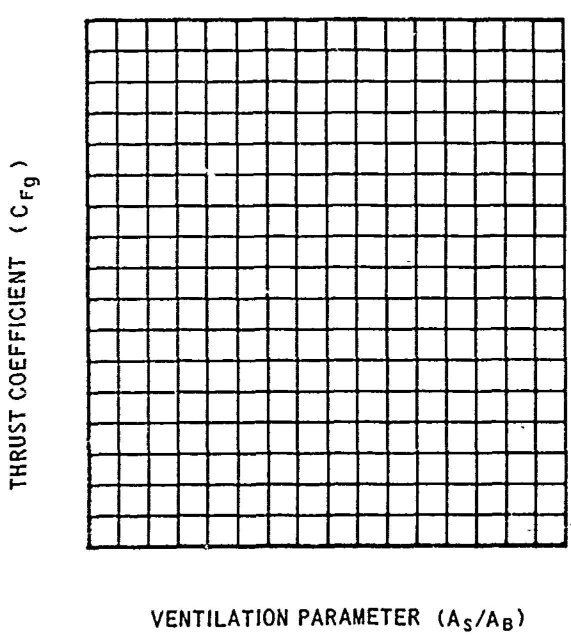


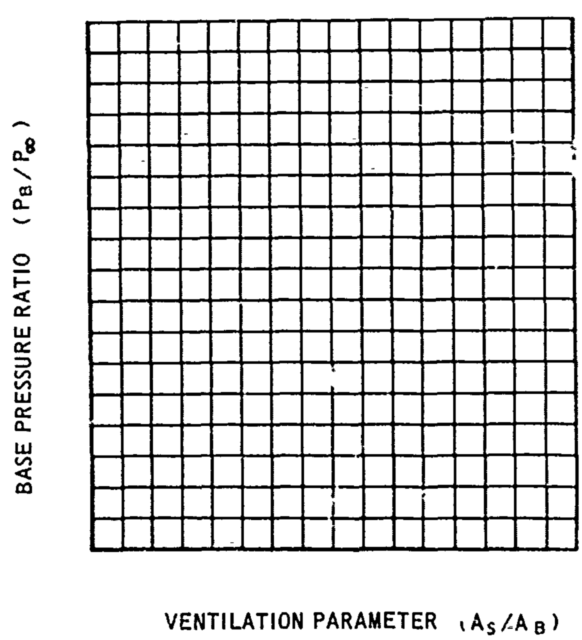
$$C_{F_g} = \frac{(\text{THRUST}-\text{DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



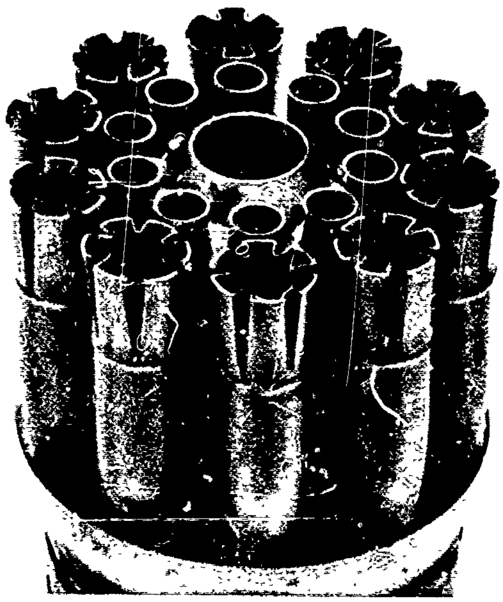






MPP 452 NOZZLE

21 TUBES, 6 SPOKE ENDS ON OUTER ROW OF TUBES, AR2.6



Description

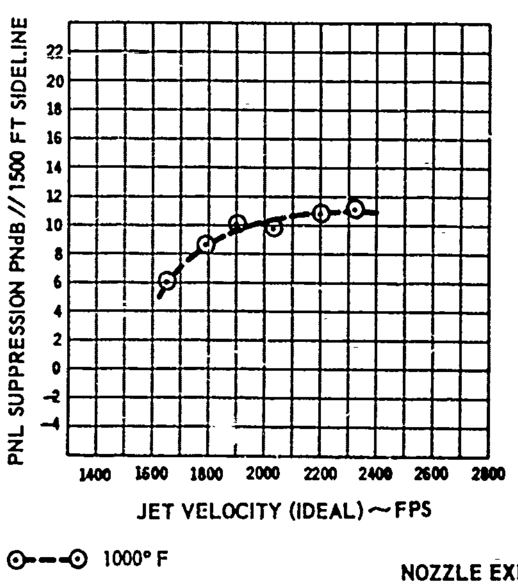
The MPP 452 nozzle is a well ventilated 21 tube nozzle. There are 10 tubes in the outer row with 6 spoke terminations on each, 10 smaller tubes in the inner row and one relatively large tube in the center.

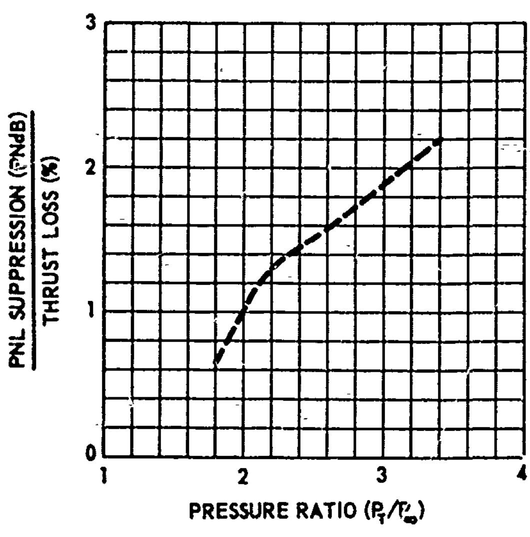
Number of Elements: 11 round convergent tubes and 10 tubes with 6-spoke ends on each

Area Ratio: 2.6

Flow Area: 6.506 square inches

Exit Cant Angle: 0 degrees

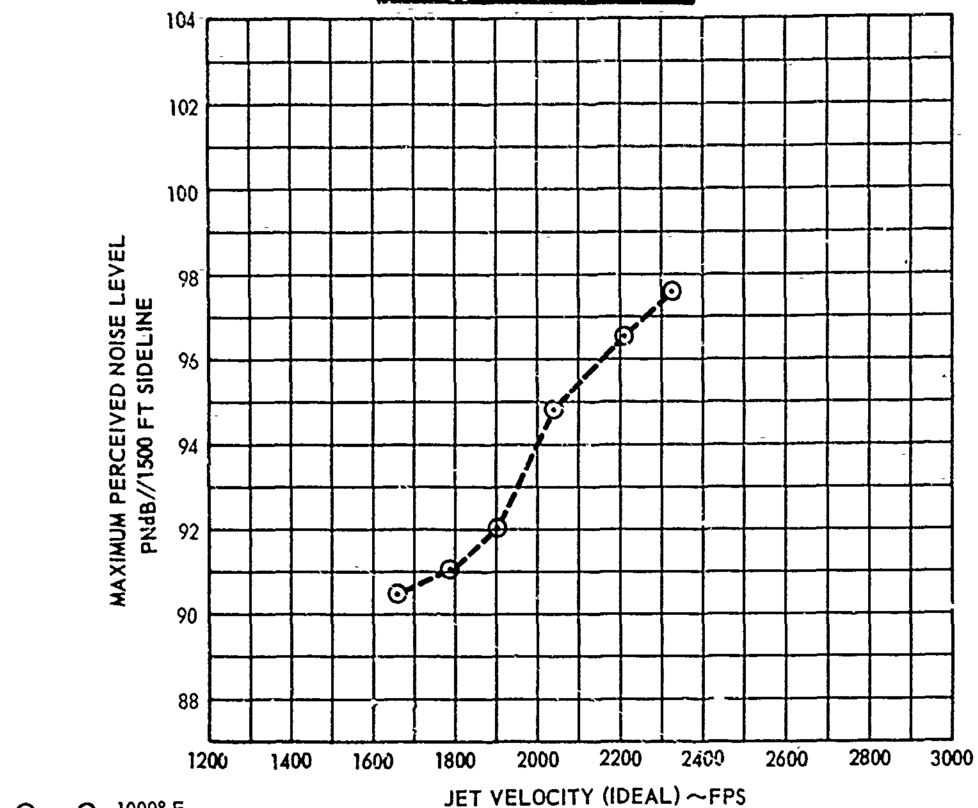




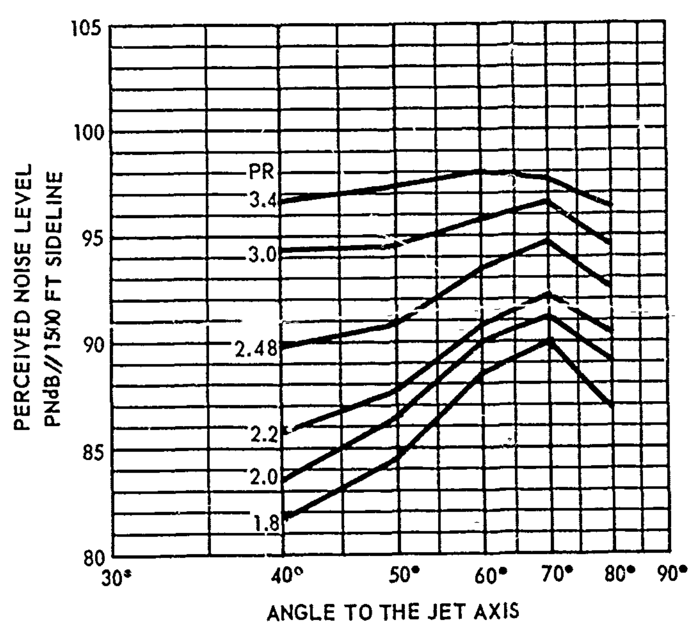
NOZZLE EXIT AREA (A_e): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

MPP 452 NOZZLE
(21 TUBES, 6 SPOKE ENDS ON OUTER ROW OF TUBES)
AR 2.6
SCALE FACTOR: 8:1



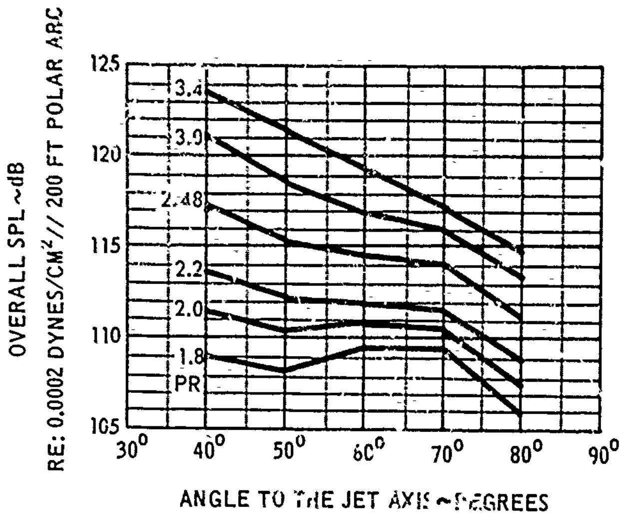
NOZZLE EXIT AREA (A_8): 3.3 FT^2



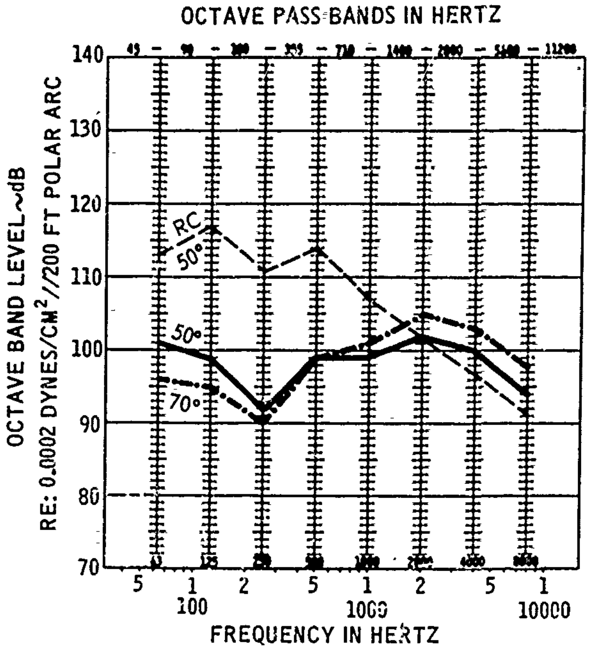
TOTAL TEMPERATURE (T_8): 1000° F

NOZZLE EXIT AREA (A_8): 3.3 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

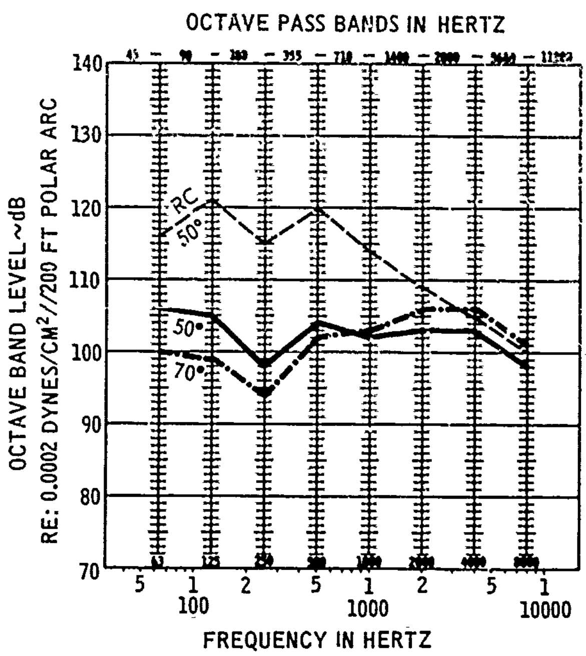


TOTAL TEMPERATURE (T_T): 1000° F
NOZZLE EXIT AREA (A_8): 3.3 FT²

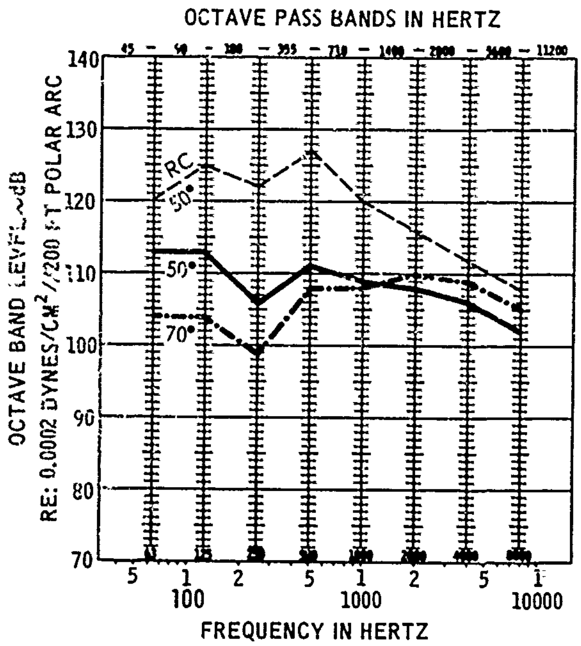


PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1000° F
JET VELOCITY (IDEAL): 1659 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²

MPP 452 NOZZLE
(21 TUBES, 6 SPOKE ENDS
ON OUTER ROW OF TUBES)
AR 2.86
SCALE FACTOR: 8:3



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1000° F
JET VELOCITY (IDEAL): 1900 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1000° F
JET VELOCITY (IDEAL): 2205 FPS
NOZZLE EXIT AREA (A_8): 3.3 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

MPP 452

(21 Tubes, 6 Spoke Ends on Outer Row of Tubes, AR 2.6)

Remarks

The MPP 452 nozzle was fabricated for the 707 airplane jet noise suppression program. It is similar to the MPP 152 nozzle except for the 6 spoke nozzle terminations on the outer row of tubes. This nozzle was retested for the SST program. Jet noise characteristics were reported in References D37 and D38.

MPP 452

Facility: Annex D (Cell #1)
Nozzle and microphone heights are 20 inches

Date: February 13, 1968

T_{amb}: 52°F

R.H.: --

Run No.	P_T/P	T_T	V_J (Ideal)	Nozzle
2378	1.8	1000°F	1659 fps	MPP 452
2379	2.0	"	1790	"
2380	2.2	"	1900	"
2381	2.48	"	2030	"
2382	3.0	"	2205	"
2382	3.4	"	2311	"
2360	1.8	1000°F	1659 fps	3.08 Inch Round Convergent
2361	2.0	"	1790	"
2362	2.2	"	1900	"
2363	2.48	"	2030	"
2364	3.0	"	2205	"
2365	3.4	"	2311	"

NOZZLE TEST DATA

OCTAVE BAND LEVEL~dB RE: 0.0002 DYNES/CM^2//25 FT

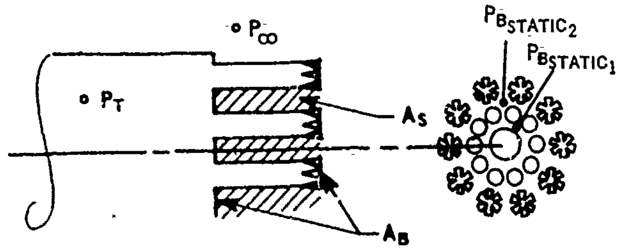
NPP-452

RUN NO.	OASPL	300	1K	2K	4K	8K	16K	32K	64K
2359 L40	139.5	126.0	131.0	138.0	128.0	124.0	117.0	108.0	107.0
2359 L50	137.2	123.0	131.0	135.0	127.0	121.0	116.0	111.0	105.0
2359 L60	132.2	118.0	122.0	129.0	126.0	123.0	117.0	108.0	109.0
2359 L70	127.6	114.0	115.0	123.0	122.0	120.0	117.0	108.0	104.0
2359 L80	126.3	110.0	116.0	121.0	120.0	120.0	116.0	106.0	105.0
2360 L40	121.8	114.0	118.0	112.0	116.0	106.0	102.0	96.0	92.0
2360 L50	120.5	113.0	117.0	111.0	114.0	107.0	102.0	97.0	91.0
2360 L60	117.2	109.0	111.0	105.0	113.0	107.0	105.0	99.0	91.0
2360 L70	113.1	104.0	106.0	102.0	108.0	105.0	103.0	99.0	92.0
2360 L80	109.8	101.0	101.0	99.0	105.0	102.0	100.0	96.0	89.0
2361 L40	124.9	116.0	120.0	116.0	120.0	113.0	108.0	103.0	97.0
2361 L50	123.3	115.0	119.0	113.0	118.0	111.0	105.0	101.0	95.0
2361 L60	119.4	111.0	113.0	107.0	115.0	110.0	108.0	102.0	95.0
2361 L70	115.5	106.0	108.0	104.0	111.0	107.0	105.0	102.0	95.0
2361 L80	111.9	102.0	103.0	102.0	107.0	104.0	103.0	99.0	92.0
2362 L40	126.4	118.0	122.0	117.0	122.0	116.0	111.0	107.0	101.0
2362 L50	125.2	116.0	121.0	115.0	120.0	114.0	109.0	105.0	100.0
2362 L60	121.6	112.0	116.0	109.0	117.0	112.0	110.0	105.0	98.0
2362 L70	118.9	107.0	109.0	105.0	112.0	109.0	108.0	104.0	98.0
2362 L80	114.0	103.0	104.0	103.0	109.0	107.0	105.0	103.0	95.0
2363 L40	128.3	119.0	123.0	118.0	124.0	117.0	114.0	109.0	104.0
2363 L50	127.5	118.0	122.0	118.0	123.0	117.0	112.0	109.0	104.0
2363 L60	123.4	113.0	117.0	112.0	119.0	114.0	113.0	108.0	102.0
2363 L70	119.0	108.0	110.0	107.0	114.0	112.0	110.0	107.0	101.0
2363 L80	116.1	104.0	106.0	104.0	111.0	109.0	106.0	106.0	99.0
2364 L40	131.4	122.0	125.0	125.0	126.0	121.0	116.0	112.0	106.0
2364 L50	130.9	120.0	125.0	122.0	127.0	120.0	116.0	112.0	108.0
2364 L60	126.9	116.0	119.0	117.0	123.0	118.0	116.0	111.0	106.0
2364 L70	123.9	110.0	113.0	117.0	119.0	116.0	115.0	111.0	106.0
2364 L80	120.6	107.0	109.0	113.0	115.0	114.0	112.0	109.0	103.0
2365 L40	132.1	123.0	127.0	124.0	127.0	121.6	116.0	112.0	107.0
2365 L50	132.1	122.0	126.0	123.0	128.0	122.0	118.0	113.0	109.0
2365 L60	128.7	117.0	121.0	118.0	125.0	120.0	118.0	113.0	107.0
2365 L70	124.9	112.0	114.0	114.0	120.0	118.0	117.0	113.0	108.0
2365 L80	122.8	108.0	110.0	115.0	117.0	117.0	114.0	111.0	106.0
2375 L45	115.6	111.0	110.0	100.0	106.0	105.0	105.0	103.0	99.0
2375 L55	113.6	106.0	105.0	100.0	106.0	104.0	106.0	105.0	100.0
2375 L60	113.6	104.0	104.0	98.0	107.0	105.0	107.0	105.0	99.0
2375 L65	113.2	103.0	102.0	97.0	106.0	105.0	107.0	105.0	101.0
2375 L75	110.9	99.0	99.0	94.0	101.0	102.0	104.0	106.0	100.0
2376 L45	119.6	115.0	114.0	105.0	111.0	109.0	108.0	105.0	101.0
2376 L55	117.0	110.0	109.0	104.0	110.0	109.0	108.0	106.0	102.0
2376 L60	116.6	107.0	107.0	102.0	111.0	109.0	109.0	106.0	101.0
2376 L65	115.5	105.0	106.0	100.0	109.0	106.0	108.0	107.0	103.0
2376 L75	113.3	102.0	102.0	98.0	104.0	105.0	106.0	108.0	102.0
2377 L45	122.5	117.0	118.0	106.0	113.0	113.0	110.0	107.0	102.0
2377 L55	119.4	112.0	112.0	107.0	113.0	111.0	110.0	107.0	103.0
2377 L60	118.7	109.0	110.0	104.0	113.0	111.0	111.0	108.0	102.0
2377 L65	117.6	107.0	108.0	103.0	112.0	110.0	110.0	108.0	104.0
2377 L75	114.8	103.0	104.0	99.0	106.0	107.0	108.0	109.0	103.0
2378 L40	109.0	104.0	101.0	92.0	98.0	99.0	102.0	99.0	93.0
2378 L50	108.2	101.0	99.0	92.0	99.0	99.0	102.0	100.0	94.0
2378 L60	109.4	99.	97.0	91.0	101.0	101.0	105.0	101.0	95.0
2378 L70	104.4	96.	95.0	90.0	99.0	101.0	105.0	103.0	98.0
2378 L80	105.9	94.0	92.0	87.0	95.0	97.0	100.0	101.0	95.0
2379 L40	111.4	107.0	105.0	94.0	100.0	100.0	102.0	101.0	96.0
2379 L50	110.3	103.0	102.0	95.0	102.0	101.0	103.0	102.0	97.0
2379 L60	110.9	101.0	99.0	93.0	104.0	102.0	106.0	102.0	97.0
2379 L70	110.6	98.0	96.0	91.0	100.0	101.0	106.0	105.0	100.0
2379 L80	107.8	95.0	94.0	90.0	97.0	99.0	102.0	[illegible]	97.0
2380 L40	113.6	110.0	107.0	98.0	102.0	102.0	103.0	[illegible]	98.0
2380 L50	112.2	106.0	105.0	98.0	104.0	102.0	103.0	104.0	98.0
2380 L60	112.0	103.0	101.0	96.0	105.0	103.0	106.0	104.0	98.0
2380 L70	111.7	100.0	99.0	94.0	102.0	103.0	106.0	106.0	101.0
2380 L80	109.1	97.0	96.0	91.0	99.0	100.0	103.0	104.0	99.0
2381 L40	117.2	113.0	112.0	102.0	105.0	106.0	106.0	104.0	100.0
2381 L50	115.2	109.0	108.0	101.0	107.0	106.0	106.0	105.0	101.0
2381 L60	114.5	105.0	104.0	99.0	108.0	106.0	108.0	106.0	101.0
2381 L70	114.1	102.0	101.0	97.0	105.0	105.0	109.0	108.0	103.0
2381 L80	111.1	99.0	98.0	95.0	101.0	102.0	105.0	106.0	101.0
2383 L40	123.6	118.0	120.0	110.0	113.0	112.0	111.0	107.0	103.0
2383 L50	121.4	115.0	116.0	108.0	114.0	112.0	110.0	108.0	103.0
2383 L60	119.3	110.0	110.0	105.0	113.0	112.0	112.0	109.0	103.0
2383 L70	117.2	105.0	105.0	101.0	110.0	109.0	111.0	110.0	106.0
2383 L80	114.7	103.0	103.0	100.0	106.0	106.0	108.0	109.0	104.0
2382 L40	121.1	116.0	117.0	107.0	110.0	110.0	109.0	108.0	102.0
2382 L50	118.8	113.0	113.0	106.0	111.0	109.0	108.0	106.0	102.0
2382 L60	117.0	108.0	107.0	102.0	111.0	109.0	110.0	107.0	102.0
2382 L70	116.0	104.0	104.0	99.0	108.0	106.0	110.0	109.0	105.0
2382 L80	113.2	101.0	101.0	94.0	104.0	104.0	107.0	108.0	102.0

D342

NOTE:THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

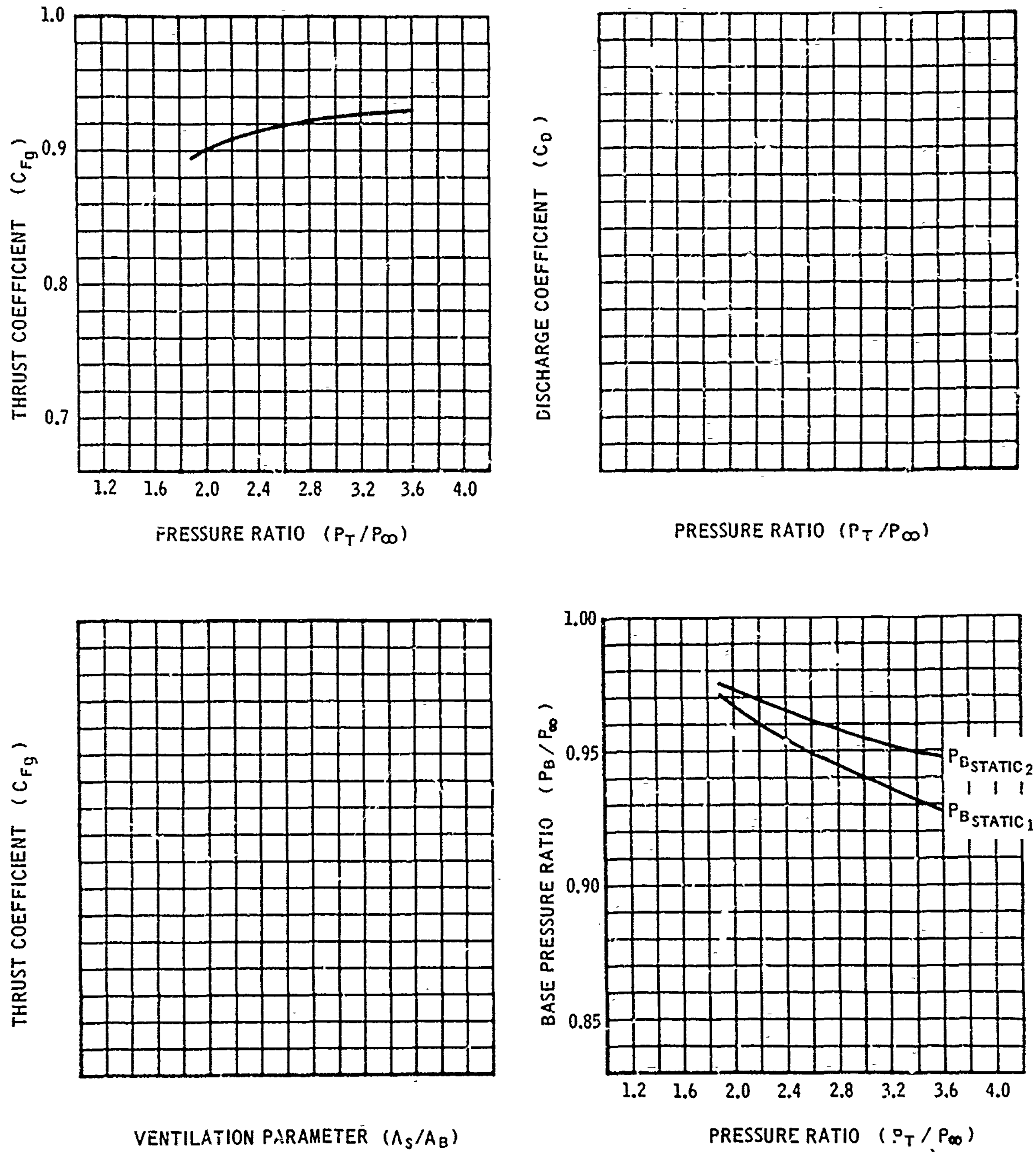
MPP 452



21 TUBES, OUTER ROW WITH GREATREX ENDS

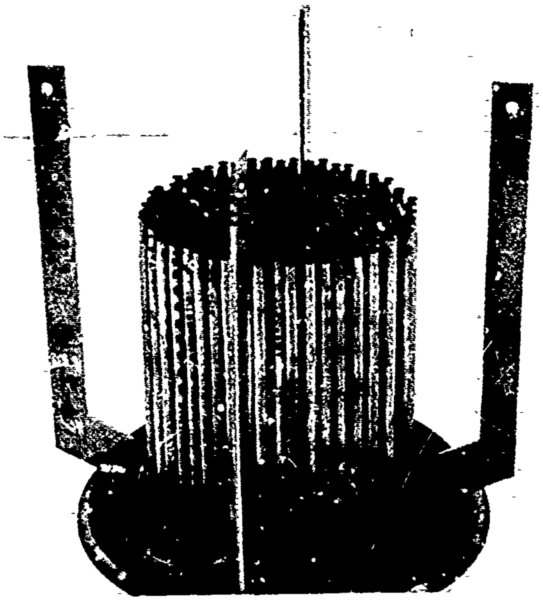
$$C_{F_g} = \frac{\text{(THRUST–DRAG) MEASURED}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{\text{(MASS FLOW) MEASURED}}{\text{IDEAL PRIMARY MASS FLOW}}$$



253 TUBE NOZZLE

(253 TUBES, AR 4.0)



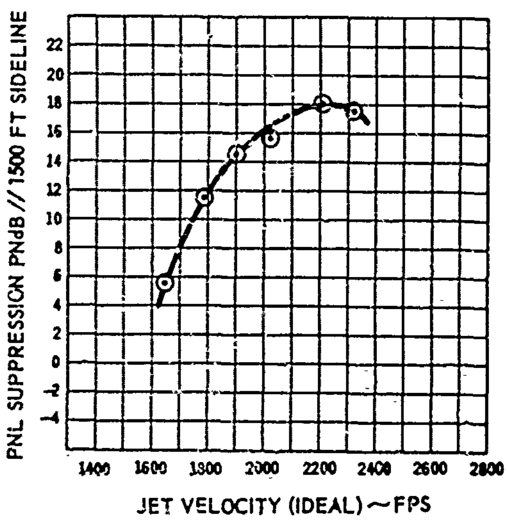
Description

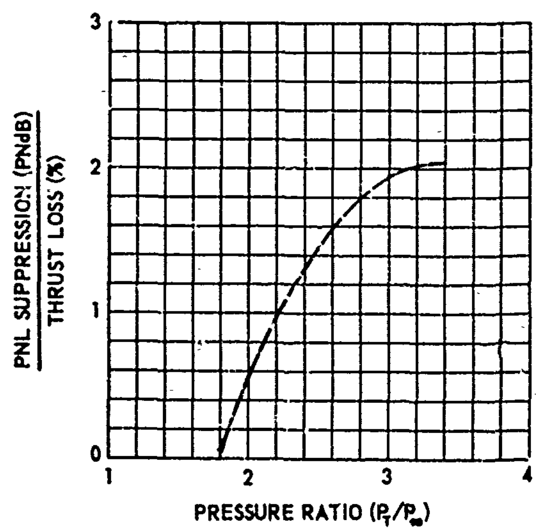
Number of Elements: 253 round tubes, nozzle ends slightly divergent

Area Ratio: 4.0

Flow Area: 6.43 square inches

Tube Length: 6 inches

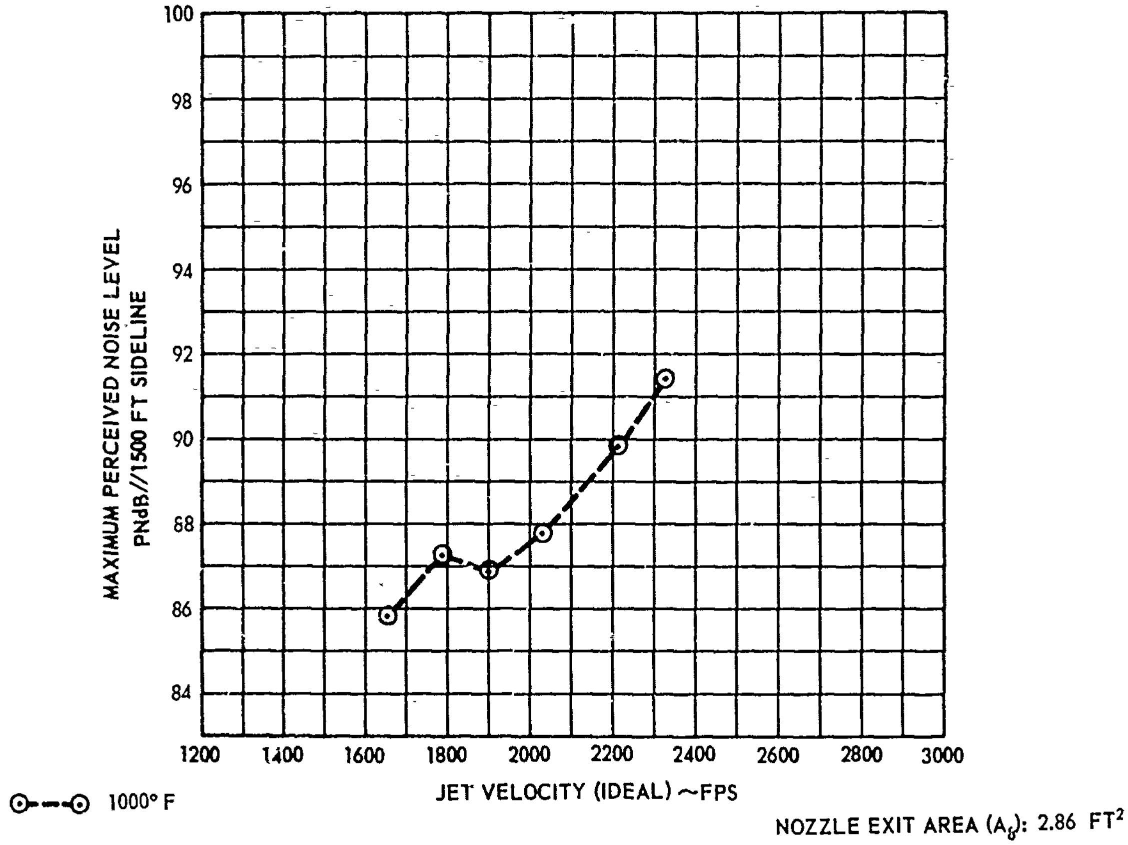


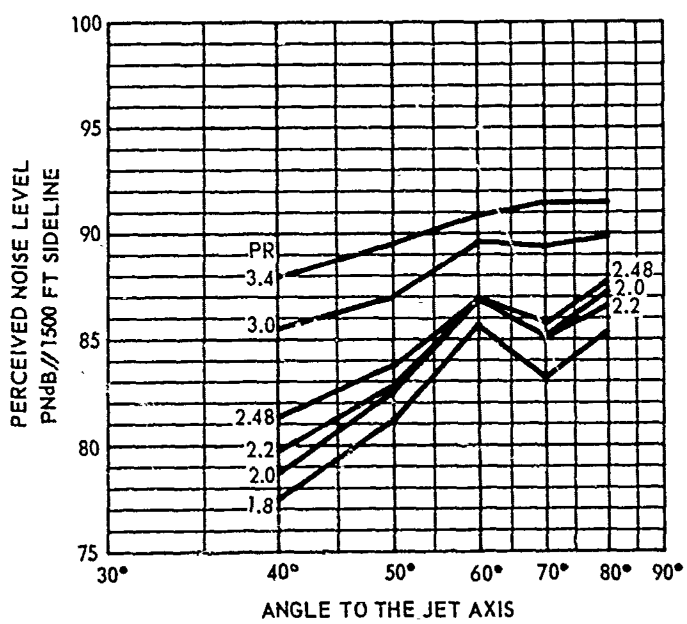


NOZZLE EXIT AREA (A_8): 2.86 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

253 TUBE NOZZLE
(253 TUBES)
AR 4.0
SCALE FACTOR: 8:1

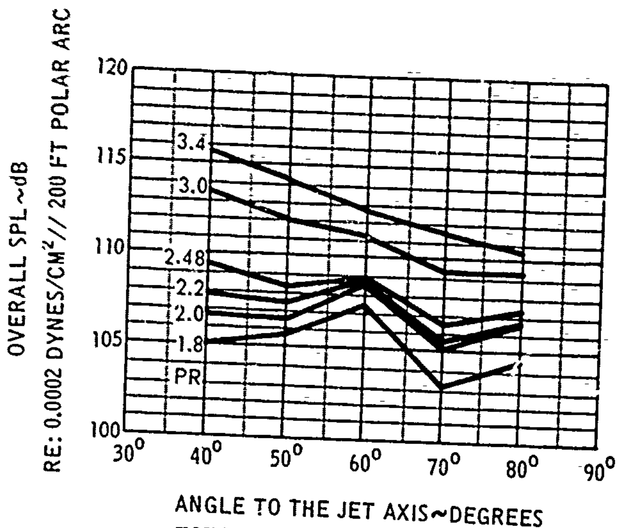




TOTAL TEMPERATURE (T_8): 1000° F

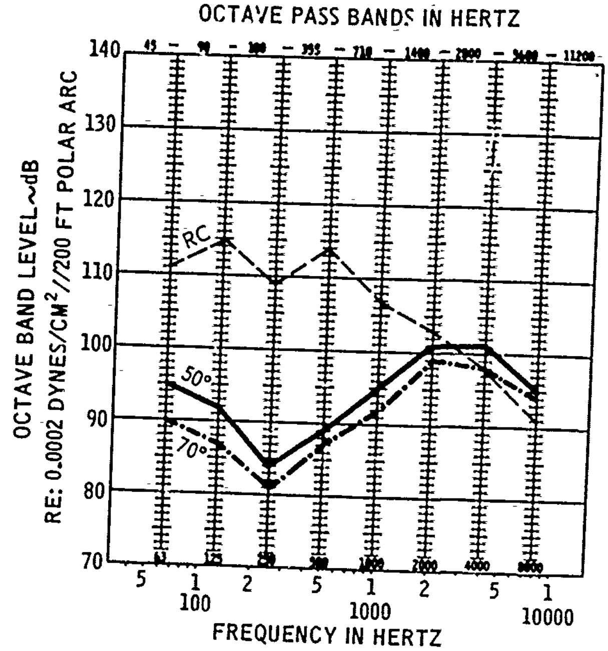
NOZZLE EXIT AREA (A_8): 2.86 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

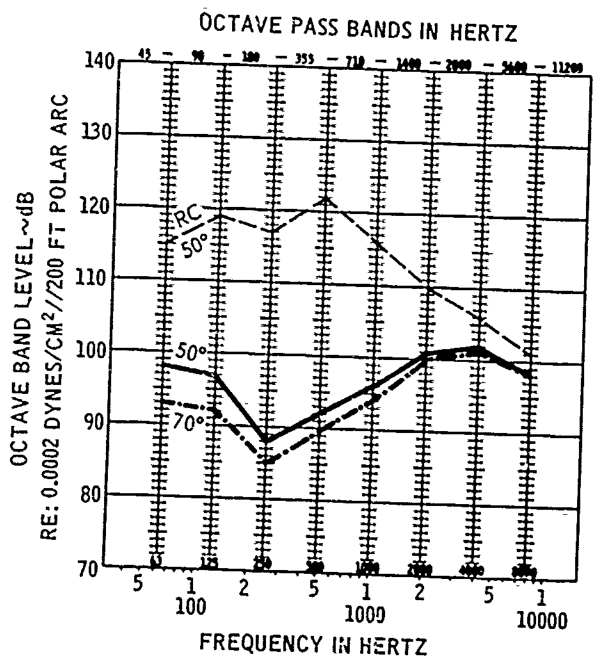


TOTAL TEMPERATURE (T_8) : 1000° F
NOZZLE EXIT AREA (A_8): 2.86 FT²

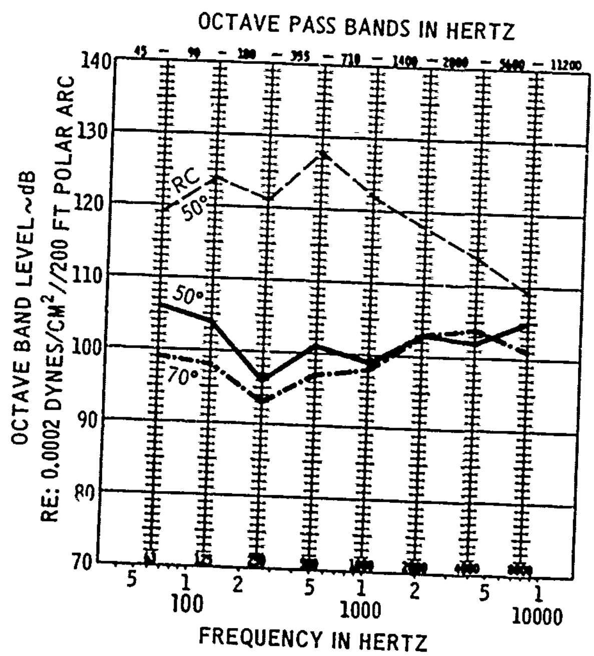
253 TUBE NOZZLE
(253 TUBES)
AR 4.0
SCALE FACTOR: 8:1



PRESSURE RATIO: 1.8
TOTAL TEMPERATURE: 1000° F
JET VELOCITY (IDEAL):
NOZZLE EXIT AREA (A_8): 2.86 FT²



PRESSURE RATIO: 2.2
TOTAL TEMPERATURE: 1000° F
JET VELOCITY (IDEAL):
NOZZLE E؛ IT AREA (A_8): 2.86 FT²



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 1000° F
JET VELOCITY (IDEAL):
NOZZLE EXIT AREA (A_8): 2.86 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

253 TUBE NOZZLE

(253 Tubes, AR 4.0)

Remarks

The jet noise characteristics of the 253 tube nozzle were reported in Reference D39. A full scale 259 tube, AR 4.0 nozzle was constructed for testing on the J-75 engine.

The full scale nozzle was intended for testing at the Boardman, Oregon, test site, however, these plans were never carried out. The model scale 253 tube nozzle and the full scale 259 tube nozzle tests would have demonstrated the validity of scaling assumptions.

253 TUBES

Facility: Annex D (Cell #1)
Nozzle and microphone heights are 20 inches.

Date: February 14, 1968

T_{amb}: 53°F

R.H.: 42%

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
2402	1.8	1000°F	1659 fps	253 Tubes
2403	2.0	"	1790	"
2404	2.2	"	1900	"
2405	2.48	"	2030	"
2406	3.0	"	2205	"
2407	3.4	"	2311	"
2384	1.8	1000°F	1659 fps	2.86 Inch Round Convergent Nozzle
2385	2.0	"	1790	"
2386	2.2	"	1900	"
2387	2.48	"	2030	"
2388	3.0	"	2205	"
2389	3.4	"	2311	"

253 TUBES
NOZZLE TEST DATA

OCTAVE BAND LEVEL—dB RE: 0.0002 DYNES/CM^2//25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
2402 L40	105.0	96.0	92.0	82.0	88.0	94.0	101.0	99.0	94.0
2402 L50	105.6	94.0	92.0	84.0	89.0	95.0	101.0	101.0	95.0
2402 L60	107.5	93.0	91.0	83.0	92.0	96.0	104.0	102.0	98.0
2402 L70	103.1	90.0	87.0	81.0	87.0	92.0	99.0	98.0	94.0
2402 L80	104.5	90.0	88.0	82.0	88.0	92.0	100.0	100.0	96.0
2403 L40	106.7	98.0	94.0	84.0	89.0	95.0	102.0	101.0	97.0
2403 L50	106.7	97.0	95.0	85.0	90.0	96.0	102.0	101.0	97.0
2403 L60	108.6	95.0	98.0	84.0	93.0	97.0	105.0	103.0	99.0
2403 L70	105.1	92.0	90.0	83.0	89.0	93.0	101.0	100.0	96.0
2403 L80	106.5	92.0	90.0	83.0	90.0	94.0	102.0	102.0	98.0
2404 L40	107.8	101.0	97.0	87.0	91.0	95.0	102.0	102.0	98.0
2404 L50	107.2	98.0	97.0	88.0	92.0	96.0	101.0	102.0	98.0
2404 L60	108.7	96.0	95.0	87.0	94.0	97.0	104.0	104.0	99.0
2404 L70	105.6	93.0	92.0	85.0	90.0	94.0	100.0	101.0	98.0
2404 L80	106.6	93.0	92.0	85.0	91.0	94.0	100.0	103.0	99.0
2405 L40	109.4	104.0	101.0	91.0	94.0	95.0	102.0	103.0	98.0
2405 L50	108.3	101.0	100.0	91.0	95.0	96.0	101.0	102.0	99.0
2405 L60	108.9	98.0	97.0	89.0	97.0	97.0	103.0	104.0	100.0
2405 L70	106.4	95.0	94.0	88.0	92.0	95.0	100.0	102.0	98.0
2405 L80	107.3	95.0	94.0	88.0	93.0	95.0	101.0	103.0	100.0
2406 L40	113.6	110.0	106.0	96.0	99.0	99.0	104.0	105.0	101.0
2406 L50	112.0	106.0	104.0	96.0	101.0	99.0	103.0	102.0	105.0
2406 L60	111.3	103.0	101.0	94.0	101.0	99.0	105.0	105.0	102.0
2406 L70	109.3	99.0	98.0	93.0	97.0	98.0	103.0	104.0	101.0
2406 L80	109.2	99.0	98.0	92.0	97.0	97.0	102.0	105.0	100.0
2407 L40	115.9	113.0	109.0	100.0	103.0	100.0	104.0	105.0	102.0
2407 L50	114.1	109.0	108.0	99.0	104.0	101.0	103.0	105.0	102.0
2407 L60	112.7	105.0	105.0	97.0	104.0	101.0	105.0	105.0	102.0
2407 L70	111.5	102.0	101.0	96.0	101.0	101.0	104.0	106.0	103.0
2407 L80	110.5	101.0	100.0	95.0	100.0	99.0	103.0	105.0	102.0
2384 L40	121.8	113.0	117.0	113.0	117.0	109.0	104.0	98.0	94.0
2384 L50	119.3	111.0	115.0	109.0	114.0	107.0	103.0	98.0	91.0
2384 L60	116.4	106.0	109.0	104.0	113.0	107.0	105.0	99.0	92.0
2384 L70	112.6	102.0	105.0	100.0	108.0	105.0	103.0	99.0	92.0
2384 L80	109.8	100.0	102.0	99.0	105.0	102.0	100.0	96.0	90.0
2385 L40	124.9	115.0	119.0	115.0	121.0	114.0	110.0	104.0	101.0
2385 L50	122.3	113.0	118.0	113.0	117.0	111.0	105.0	102.0	97.0
2385 L60	119.3	108.0	112.0	107.0	116.0	110.0	108.0	102.0	96.0
2385 L70	115.3	103.0	107.0	103.0	111.0	108.0	106.0	102.0	96.0
2385 L80	112.0	101.0	103.0	101.0	107.0	105.0	103.0	100.0	93.0
2386 L40	128.2	117.0	120.0	120.0	125.0	118.0	113.0	109.0	105.0
2386 L50	125.7	115.0	119.0	117.0	122.0	116.0	110.0	106.0	101.0
2386 L60	121.2	110.0	111.0	110.0	118.0	113.0	111.0	105.0	99.0
2386 L70	117.2	105.0	108.0	105.0	113.0	110.0	108.0	104.0	98.0
2386 L80	112.2	101.0	103.0	102.0	107.0	105.0	104.0	100.0	93.4
2387 L40	129.5	119.0	123.0	119.0	126.0	119.0	115.0	111.0	108.0
2387 L50	128.3	117.0	122.0	117.0	125.0	118.0	114.0	110.0	106.0
2387 L60	124.2	112.0	116.0	111.0	121.0	115.0	114.0	109.0	103.0
2387 L70	119.3	107.0	110.0	106.0	115.0	112.0	111.0	107.0	102.0
2387 L80	116.2	104.0	106.0	105.0	111.0	109.0	109.0	105.0	99.0
2388 L40	130.7	121.0	125.0	122.0	126.0	120.0	116.0	112.0	109.0
2388 L50	131.3	119.0	124.0	121.0	128.0	122.0	118.0	114.0	109.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

253 TUBES

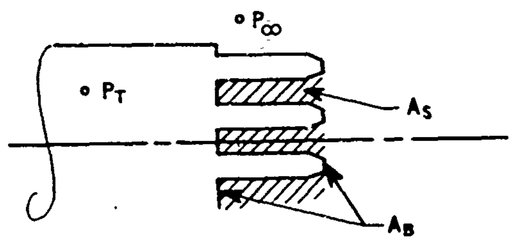
NOZZLE TEST DATA

OCTAVE BAND LEVEL ~ dB RE: 0.0002 DYNES/CM^2//25 FT

RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
2388 L60	126.3	113.0	117.0	114.0	123.0	118.0	117.0	112.0	107.0
2388 L70	122.8	108.0	111.0	110.0	118.0	116.0	116.0	111.0	107.0
2388 L80	120.2	106.0	108.0	108.0	115.0	114.0	113.0	109.0	104.0
2389 L40	132.2	123.0	127.0	124.0	127.0	121.0	117.0	113.0	110.0
2389 L50	132.2	121.0	126.0	123.0	128.0	123.0	118.0	115.0	110.0
2389 L60	129.1	115.0	120.0	119.0	126.0	120.0	118.0	114.0	108.0
2389 L70	124.8	110.0	113.0	115.0	120.0	118.0	117.0	113.0	108.0
2389 L80	122.3	107.0	111.0	113.0	117.0	116.0	114.0	111.0	105.0

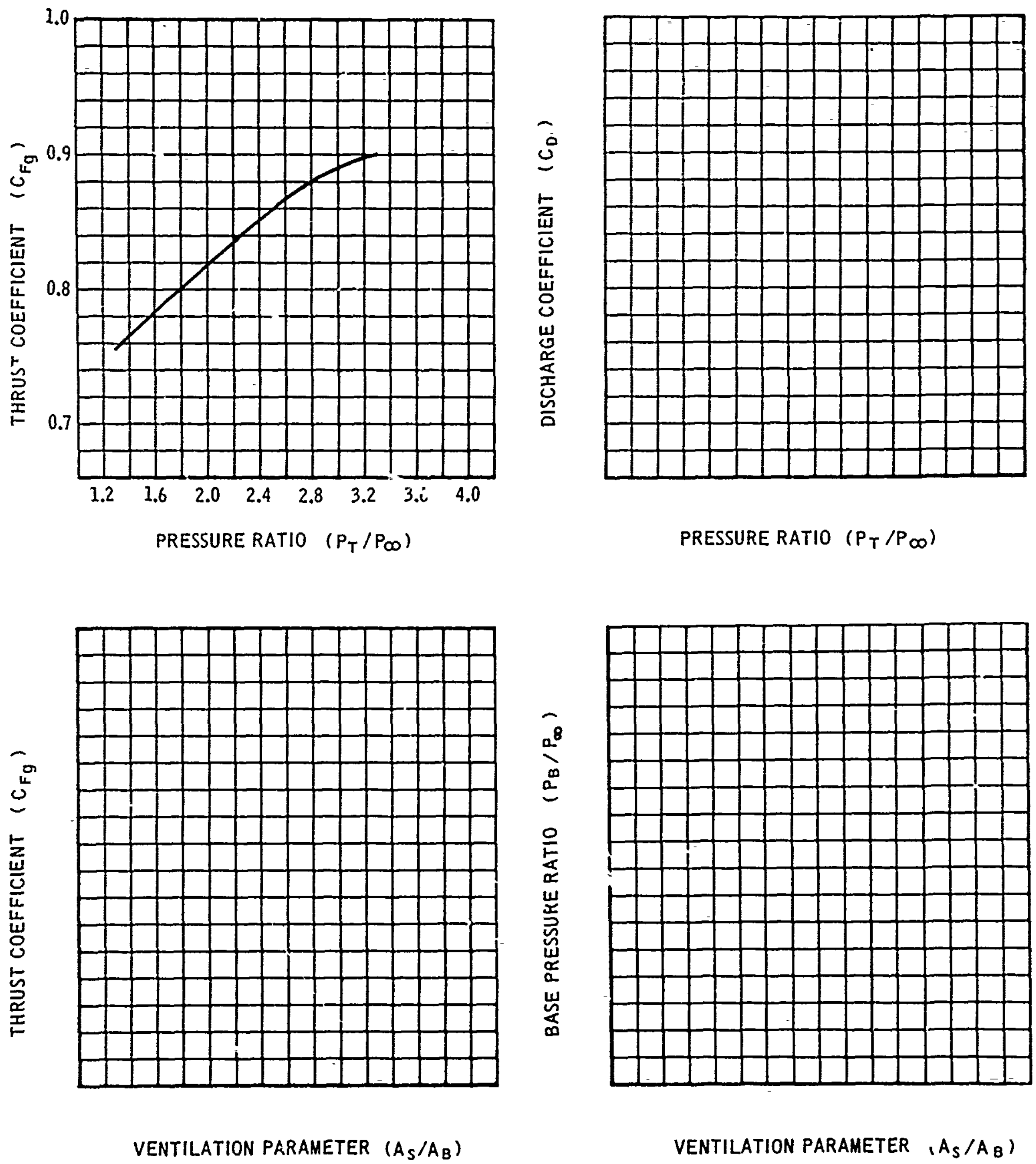
NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

253 TUBE NOZZLE

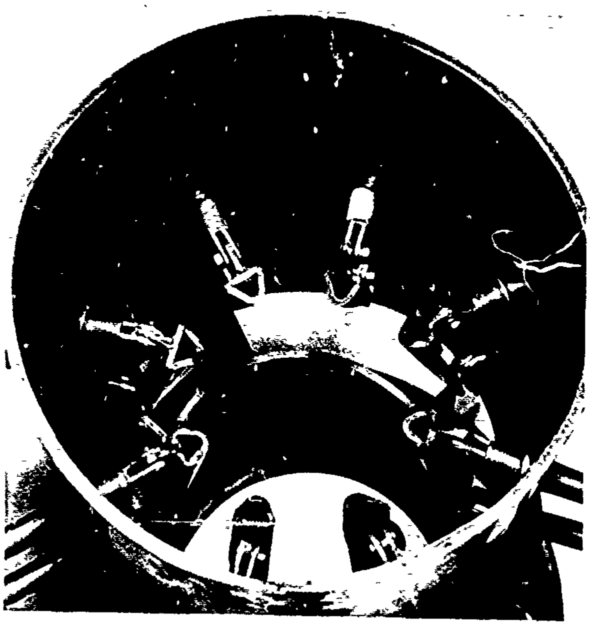


$$C_{Fg} = \frac{(\text{THRUST-DRAG})_{\text{MEASURED}}}{\text{IDEAL PRIMARY THRUST}}$$

$$C_D = \frac{(\text{MASS FLOW})_{\text{MEASURED}}}{\text{IDEAL PRIMARY MASS FLOW}}$$



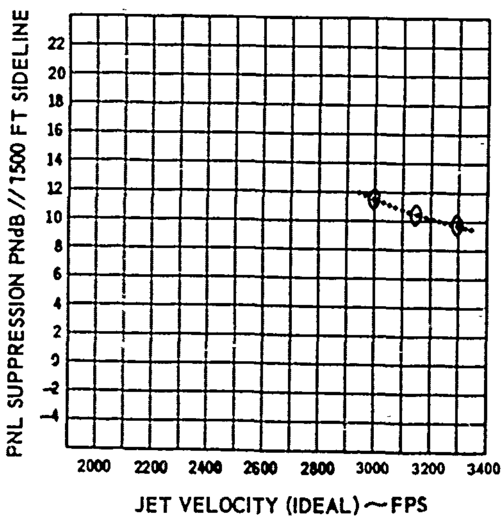
29xx8400 NOZZLE

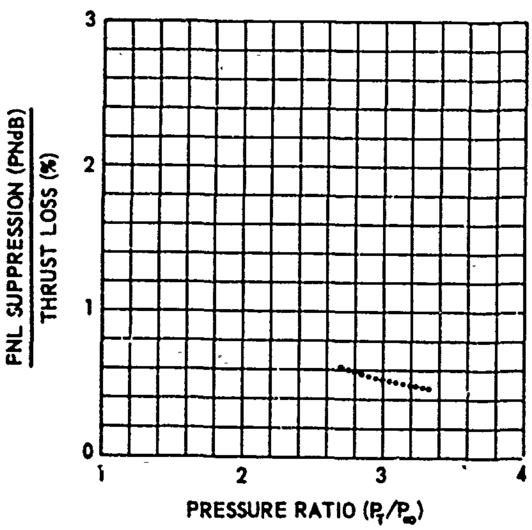


(RC PRIMARY NOZZLE AND EJECTOR WITH 8 CHUTES)

Description

The primary nozzle is a 4.1-inch diameter round convergent nozzle set 2.25 inches upstream from the ejector throat. The ejector has a total length of 9.1 inches. The diameter of the ejector inlet is 7.3 inches, tapering down to a diameter of 6.35 inches in an axial distance of 2.98 inches. The remainder of the ejector is cylindrical. Eight chutes are situated in the fully expanded jet flow. The chutes are 1.5 inches long and 0.45 inches wide set at an angle of 37.4 degrees relative to the jet axis. The leading edge of the chutes is positioned about 0.75 inches downstream of the primary nozzle exit or 1.5 inches upstream of the ejector throat. Ejector area to primary nozzle exit area ratio is 2.4. Chute penetration of the jet is approximately 40%.

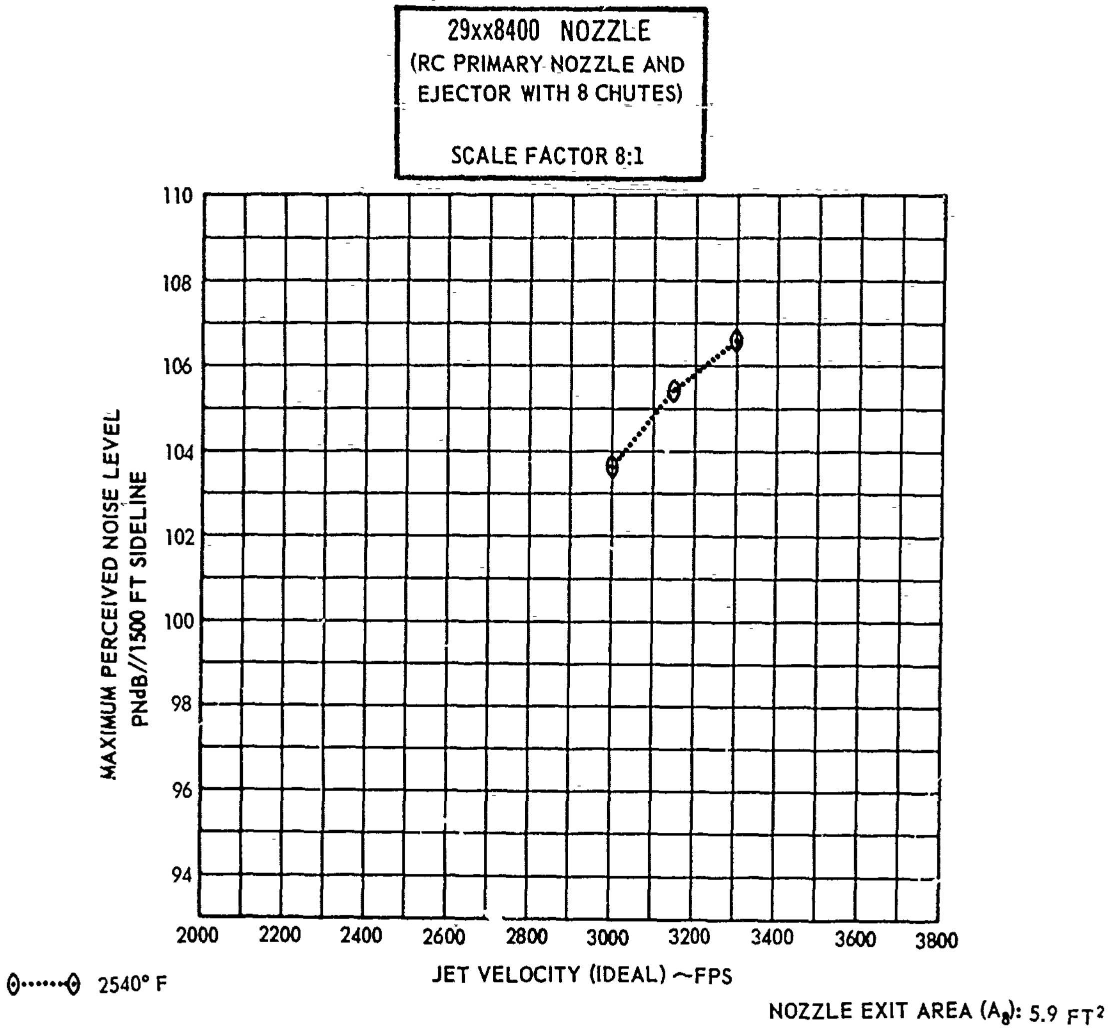


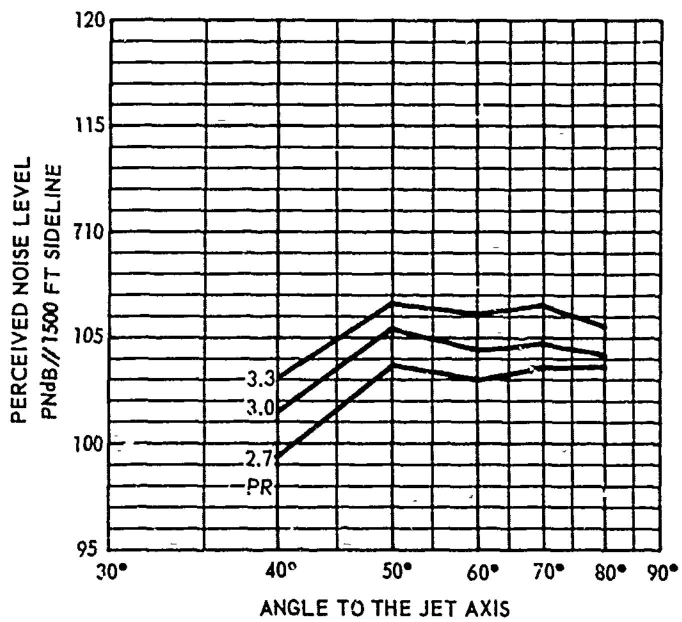


2540° F

NOZZLE EXIT AREA (A_8): 5.9 FT^2

DATA INCLUDES GROUND REFLECTION INTERFERENCE

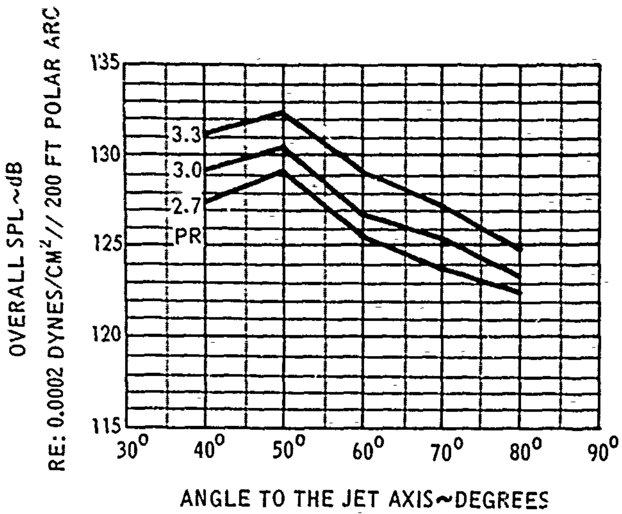




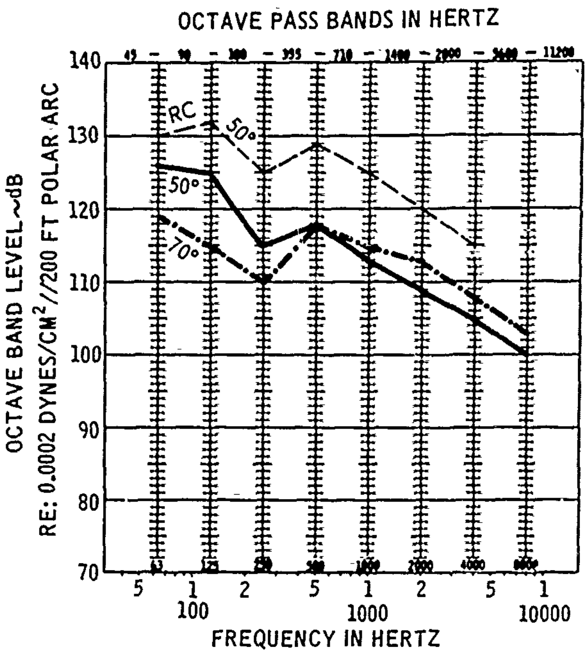
TOTAL TEMPERATURE (T_8): 2540° F

NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE



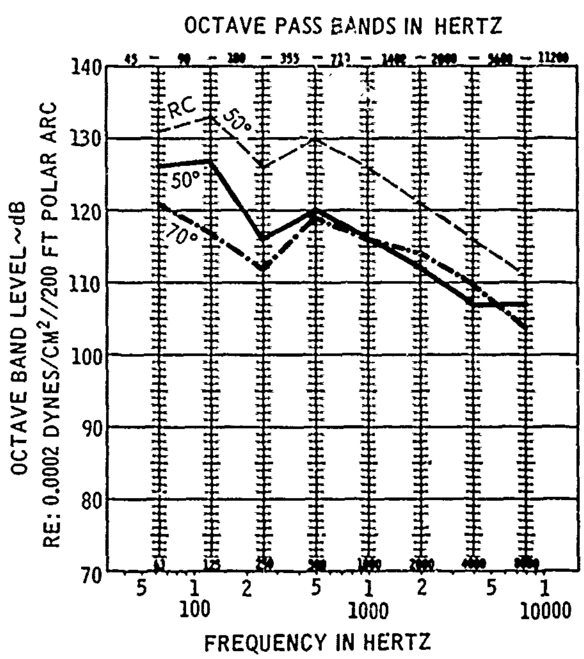
TOTAL TEMPERATURE (T_8) : 25⁄0° F
NOZZLE EXIT AREA (A_8) : 5.9 FT²



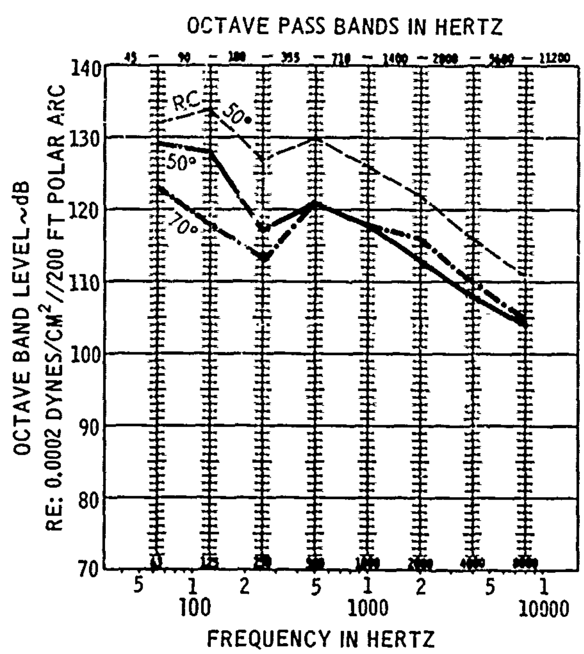
PRESSURE RATIO: 2.7
TOTAL TEMPERATURE: 2540° F
JET VELOCITY (IDEAL): 3000 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

29xx8400 NOZZLE
(RC PRIMARY NOZZLE
AND EJECTOR WITH 8 CHUTES)

SCALE FACTOR: 8:1



PRESSURE RATIO: 3.0
TOTAL TEMPERATURE: 2540° F
JET VELOCITY (IDEAL): 3150 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²



PRESSURE RATIO: 3.3
TOTAL TEMPERATURE: 2540° F
JET VELOCITY (IDEAL): 3300 FPS
NOZZLE EXIT AREA (A_8): 5.9 FT²

DATA INCLUDES GROUND REFLECTION INTERFERENCE

29-8400

(RC Primary Nozzle and Ejector with 8 Chutes)

Remarks

Chuted ejector configuration 29 xx 8400 represents the "best" angle of attack chute position tested for a parametric study conducted during 1967. Fifteen ejector types and 28 chute types were tested in about 70 different combinations, see Reference D40. Test results for the 29 xx 8400 model configuration are reported in References D41, D42 & D43. The conclusion was that chuted ejector configurations where the chutes intercept the fully expanded flow can result in significant noise suppression but only with an extravagant loss in thrust.

29-8400

Facility: Annex D (Cell #1)
Nozzle and Microphone Heights are 20 Inches.

Date: January 24, 1968

T_{amb}: 51°F

R. H.: 92%

Run No.	P_T/P_∞	T_T	V_J (Ideal)	Nozzle
2097	2.7	2540°F	3000 fps	29xx8400
2098	3.0	"	3150	"
2099	3.3	"	3300	"
2091	2.7	2540°F	3000 fps	4.1 Inch Round Convergent Nozzle
2092	3.0	"	3150	"
2093	3.3	"	3300	"

NOZZLE TEST DATA

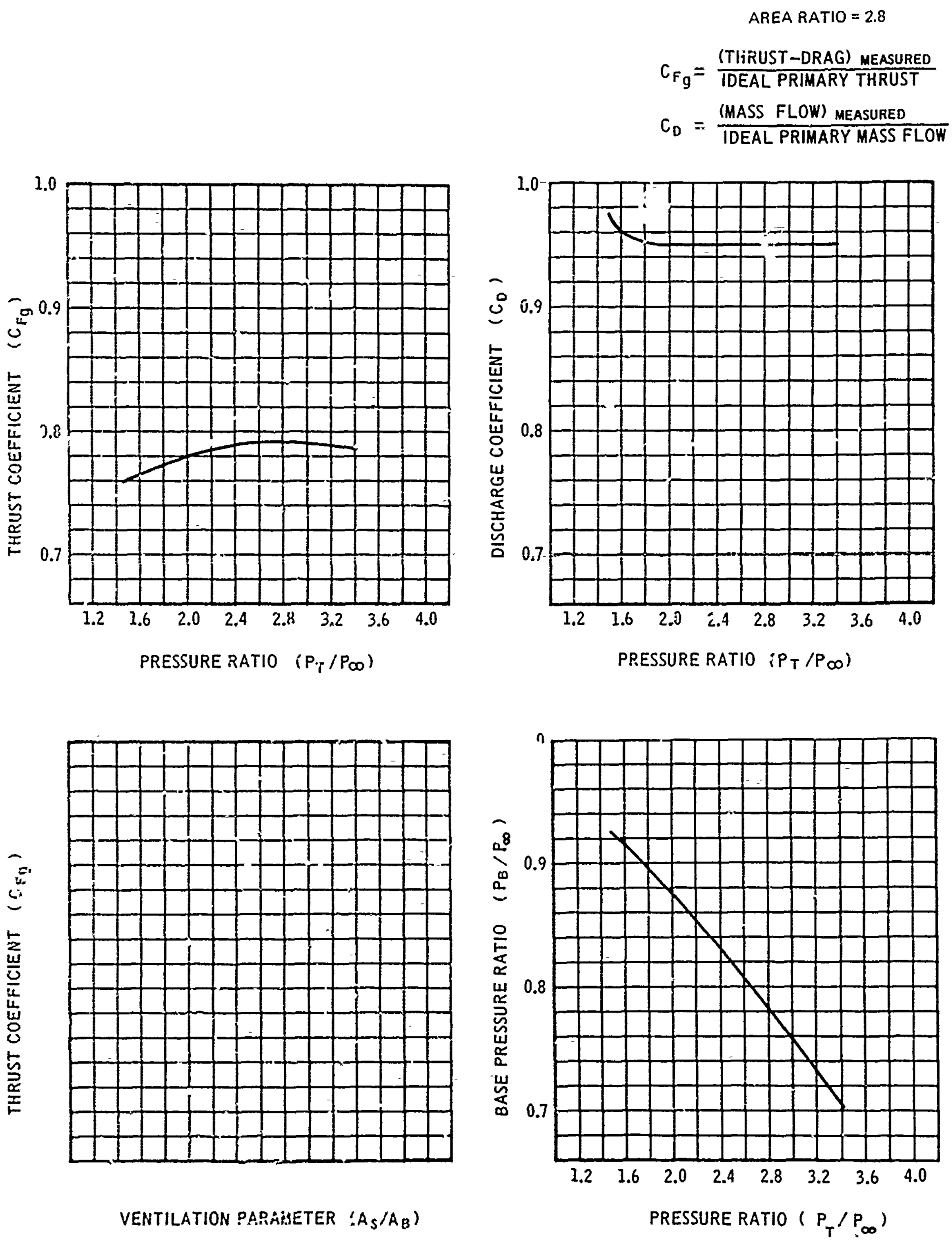
OCTAVE BAND LEVEL—dB RE: 0.0002 DYNES/CM²//25 FT

29[illegible]8400

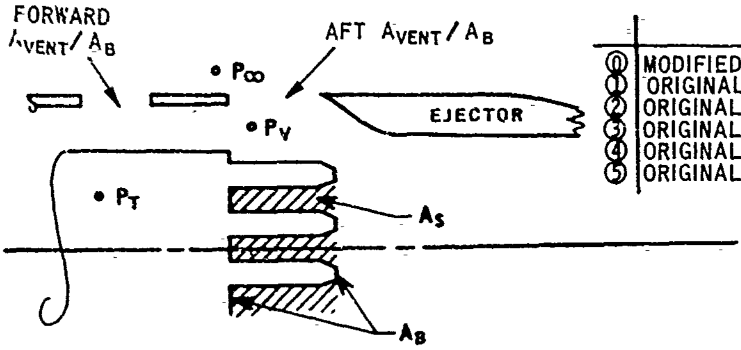
RUN NO.	OASPL	500	1K	2K	4K	8K	16K	32K	64K
2097 L40	127.5	124.0	124.0	113.0	114.0	109.0	106.0	102.0	98.0
2097 L50	129.2	126.0	125.0	115.0	118.0	113.0	109.0	105.0	100.0
2097 L60	125.8	122.0	119.0	112.0	119.0	114.0	112.0	107.0	101.0
2097 L70	123.9	119.0	115.0	110.0	118.0	115.0	113.0	108.0	103.0
2097 L80	122.6	116.0	111.0	108.0	116.0	116.0	115.0	110.0	103.0
2098 L40	129.2	125.0	126.0	116.0	117.0	112.0	108.0	103.0	100.0
2098 L50	130.4	126.0	127.0	116.0	120.0	116.0	112.0	107.0	107.0
2098 L60	126.9	123.0	120.0	113.0	120.0	116.0	114.0	109.0	103.0
2098 L70	125.4	121.0	117.0	112.0	119.0	116.0	114.0	110.0	104.0
2098 L80	123.3	117.0	113.0	109.0	117.0	110.0	115.0	110.0	104.0
2099 L40	131.2	128.0	127.0	117.0	119.0	115.0	111.0	106.0	103.0
2099 L50	132.3	129.0	128.0	117.0	121.0	118.0	113.0	108.0	104.0
2099 L60	129.2	126.0	121.0	114.0	122.0	118.0	116.0	110.0	105.0
2099 L70	127.2	123.0	118.0	113.0	121.0	118.0	116.0	110.0	105.0
2099 L80	124.9	120.0	114.0	111.0	118.0	117.0	116.0	111.0	105.0
2091 L40	132.8	129.0	128.0	121.0	124.0	118.0	114.0	108.0	104.0
2091 L50	136.2	130.0	132.0	125.0	129.0	125.0	120.0	115.0	-0.0
2091 L60	136.3	127.0	128.0	125.0	133.0	127.0	124.0	119.0	113.0
2091 L70	131.7	123.0	123.0	120.0	128.0	123.0	120.0	115.0	110.0
2091 L80	127.1	117.0	116.0	116.0	123.0	120.0	118.0	113.0	106.0
2092 L40	133.9	129.0	130.0	123.0	125.0	119.0	116.0	110.0	105.0
2092 L50	137.2	131.0	133.0	126.0	130.0	126.0	121.0	116.0	111.0
2092 L60	136.9	128.0	129.0	126.0	133.0	128.0	125.0	119.0	114.0
2092 L70	132.4	125.0	124.0	120.0	128.0	124.0	121.0	116.0	111.0
2092 L80	128.4	119.0	117.0	117.0	124.0	122.0	119.0	114.0	107.0
2093 L40	134.7	130.0	131.0	124.0	125.0	120.0	116.0	110.7	106.0
2093 L50	137.9	132.0	134.0	127.0	130.0	126.0	122.0	116.0	111.0
2093 L60	137.8	130.0	130.0	127.0	134.0	128.0	125.0	120.0	114.0
2093 L70	133.6	127.0	125.0	122.0	129.0	125.0	122.0	117.0	112.0
2093 L80	129.6	121.0	118.0	118.0	125.0	123.0	120.0	115.0	108.0

NOTE: THIS DATA INCLUDES GROUND REFLECTION INTERFERENCE

97 HOLE BASE PLATE FOR THE NSC-82



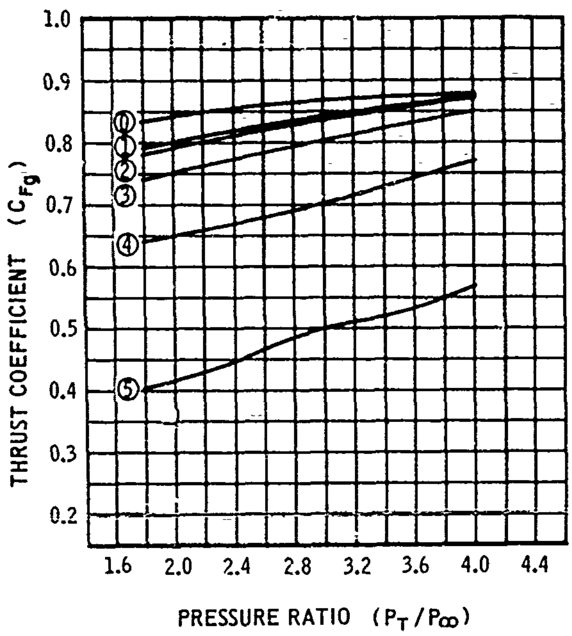
NSC-82--(97 TUBES, AREA RATIO = 2.8)

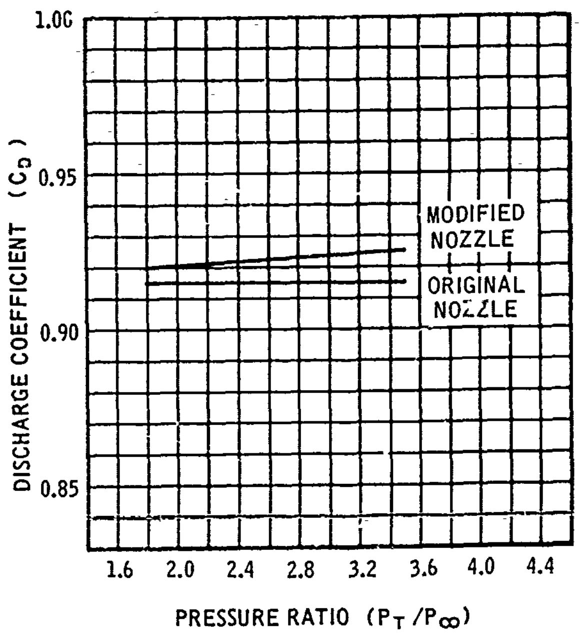


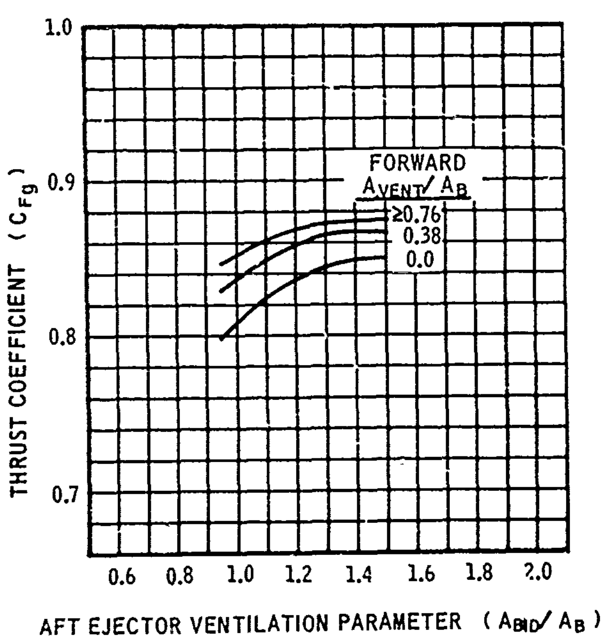
	CONFIGURATION
0	MODIFIED PRIMARY
1	ORIGINAL PRIMARY — NO SHROUD
2	ORIGINAL PRIMARY & SHROUD–ALL DOORS OPEN
3	ORIGINAL PRIMARY & SHROUD–AFT DOORS OPEN
4	ORIGINAL PRIMARY & SHROUD–FORWARD DOORS OPEN
5	ORIGINAL PRIMARY & SHROUD–NO DOORS OPEN

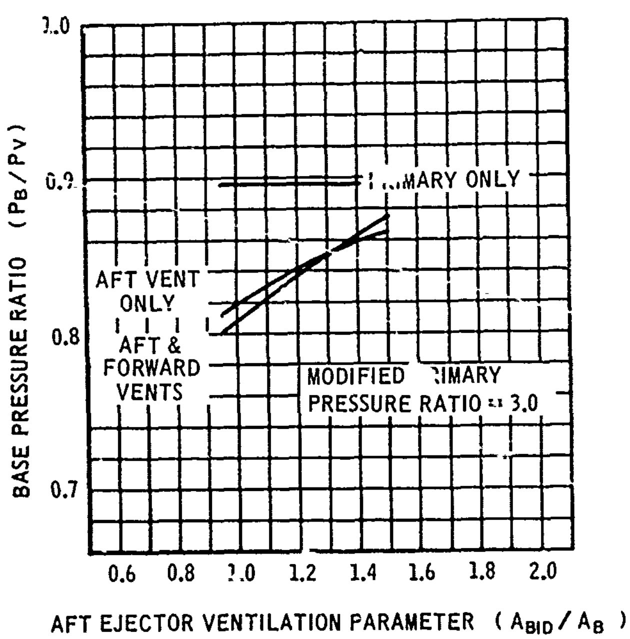
$$C_{F_g} = \frac{\text{(THRUST–DRAG) MEASURED}}{\text{IDEAL PRIMARY THRUST}}$$

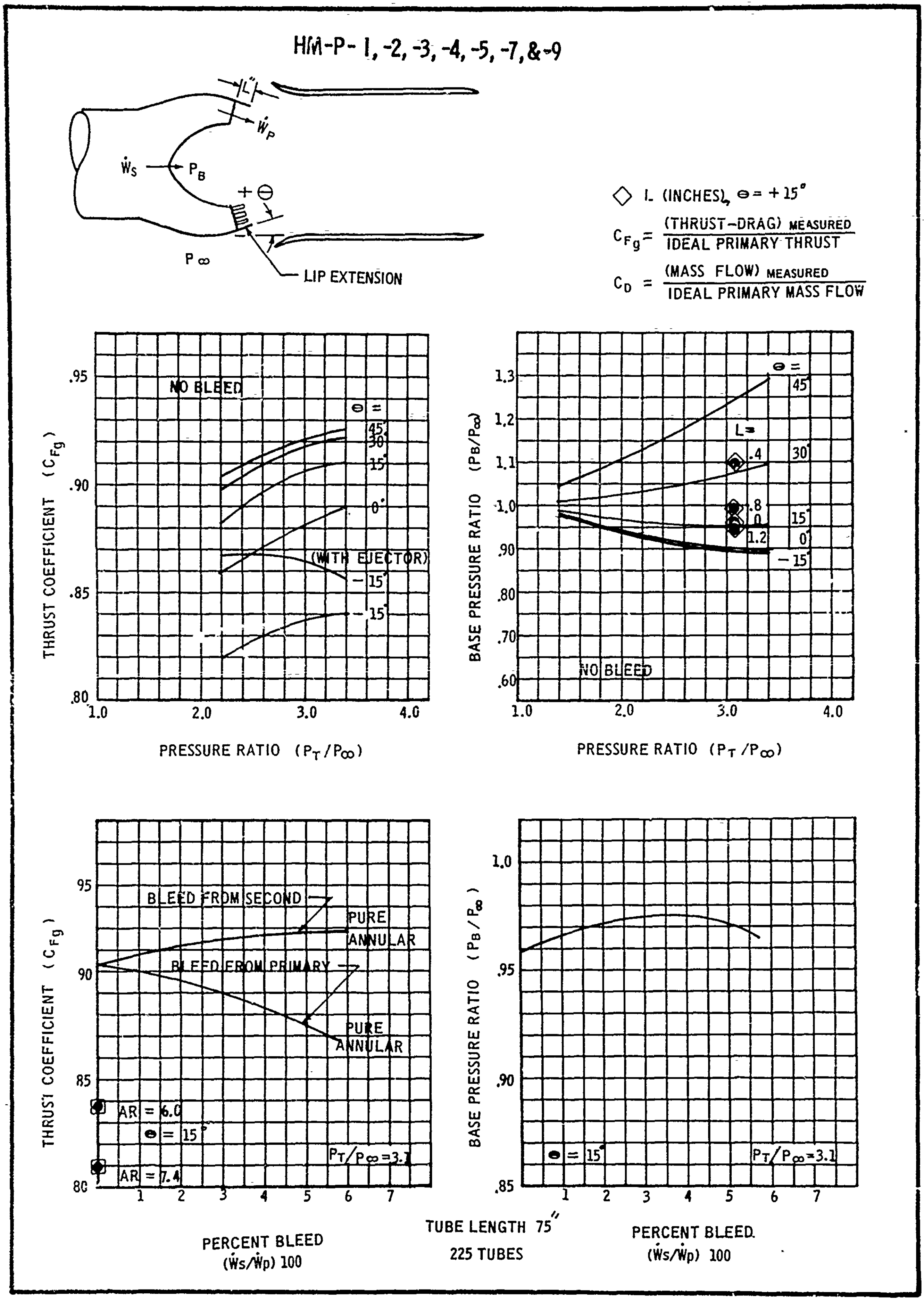
$$C_D = \frac{\text{(MASS FLOW) MEASURED}}{\text{IDEAL PRIMARY MASS FLOW}}$$










HM-P- 1, -2, -3, -4, -5, -7, & -9
L"
$\dot{W}_P$
$\dot{W}_S$
P_B
+ ⊖
P_∞
LIP EXTENSION
◇ L (INCHES), ⊖ = + 15°
$C_{F_g} = \frac{\text{(THRUST−DRAG) MEASURED}}{\text{IDEAL PRIMARY THRUST}}$
$C_D = \frac{\text{(MASS FLOW) MEASURED}}{\text{IDEAL PRIMARY MASS FLOW}}$
NO BLEED
⊖ =
45°
30°
15°
0°
(WITH EJECTOR)
− 15°
− 15°
THRUST COEFFICIENT (C_{F_g})
PRESSURE RATIO (P_T/P_∞)
BASE PRESSURE RATIO (P_B/P_∞)
L=
.4
.8
0
1.2
NO BLEED
BLEED FROM SECOND
PURE ANNULAR
BLEED FROM PRIMARY
PURE ANNULAR
AR = 6.0
⊖ = 15°
AR = 7.4
P_T/P_∞=3.1
⊖ = 15°
P_T/P_∞=3.1
PERCENT BLEED ($\dot{W}s/\dot{W}p$) 100
TUBE LENGTH 75"
225 TUBES
PERCENT BLEED ($\dot{W}s/\dot{W}p$) 100

D.3 REFERENCES

D1 Coordination sheet SST-ANPD-18, "Noise Suppression Characteristics of the 6-Lobe Multislot and 24-Spoke Nozzles," R. B. Tate, August 17, 1967.

D2 E. A. Wolff and R. B. Tate, *SST High Jet Noise Suppression Program Acoustic Results, Boeing-Annex D, Scale Model Nozzle Facility (1967)*, test report T6A11488-1, The Boeing Company, June 1969.

D3 Coordination sheet SST-ANPD-58, "Noise Characteristics of the Pure Annulus Nozzle (Area Ratio = 4)," C. W. Miller, March 25, 1968.

D4 Coordination sheet SST-ANPD-64, "Comparison of Pure Annulus and 60-Lobe Annulus Noise Characteristics," C. W. Miller, May 7, 1968.

D5 Coordination sheet SST-ANPD-129, "Thrust Performance and Noise Suppression Characteristics of the Pure Annular Nozzle Series–HM-AP-12," R. A. Lipka and C. W. Miller, November 1, 1968.

D6 Coordination sheet SST-ANPD-22, "Effect of Power Setting on the Jet Noise Suppression Characteristics of a 6-Lobe Greatrex Nozzle (HM-AP-15)," R. B. Tate, September 11, 1967.

D7 Coordination sheet SST-ANPD-16, "A Preliminary Analysis of 37-Tube Array Jet Nozzles, With and Without Greatrex Nozzle Tube Terminations," C. P. Wright, August 16, 1967.

D8 Coordination sheet SST-ANPD-45, "A Preliminary Analysis of 37-Tube Array Jet Nozzles with 12-Lobe Greatrex–Jet Terminations at 1500° F and Area Ratios of 3.33, 4.0, 4.65, 5.2, and 8.0," C. P. Wright, January 16, 1968.

D9 Coordination sheet SST-ANPD-94, "Additional Acoustic Data Analysis of the 37-Tube Jet Nozzles With 12-Lobe Greatrex-Type Terminations," C. P. Wright, August 7, 1968.

D10 Coordination sheet SST-ANPD-70, "Preliminary Acoustic Report on Model Scale Tests of a Coanda-Type Nozzle (HM-AP-20)," J. R. Alberti, June 7, 1968.

D11 Coordination sheet SST-ANPD-17, "Model Tests of the HM-AP-22, 12-Spoke Jet Noise Suppressor Series," J. R. Alberti, August 21, 1967.

D12 Coordination sheet SST-ANPD-40, "Preliminary Test Results of the Internally Ventilated Jet Noise Suppressor (HM-AP-23)," J. R. Alberti, December 27, 1967.

D13 Coordination sheet SST-ANPD-46, "Noise Characteristics of a Five-Slot (Area Ratio = 3.0) HM-AP-24 Nozzle," C. W. Miller, January 19, 1968.

D14 Coordination sheet SST-ANPD-51, "Preliminary Analysis of the 24-Spoke (Area Ratio = 6.0) Nozzle Noise Suppression Characteristics," R. B. Tate, February 21, 1968.

D15 Coordination sheet SST-ANPD-36, "Preliminary Analysis of the 24-Spoke (Area Ratio = 4.0) Nozzle Noise Suppression Characteristics," R. B. Tate, December 21, 1967.

D16 Coordination sheet SST-ANPD-136, "Acoustic and Thrust Performance Test Report and Analysis of a 270-Tube Annular Nozzle (HM-AP-34)," C. P. Wright and R. A. Lipka, January 28, 1969.

D17 Coordination sheet SST-ANPD-82, "Noise Characteristics of the 60-Lobe Annulus With Concentric Rings," C. E. Burton and C. W. Miller, July 29, 1968.

D18 Coordination sheet SST-ANPD-186, "Noise Suppression Capability of 60-Lobe Annulus (10° Canted Flow) With and Without Conical Centerbody Plugs," R. B. Tate and C. W. Miller, July 29, 1969.

D19 Coordination sheet SST-ANPD-52, "Preliminary Acoustics Report on Model Scale Tests of 37 Plain-Ended-Tube Nozzles," J. R. Alberti, March 18, 1968.

D20 Coordination sheet SST-ANPD-77, "Model Scale Retest of 37 Plain-Ended-Tube Nozzle With an Area Ratio of 4.65," D. H. Underwood, July 11, 1968.

D21 Coordination sheet SST-ANPD-85, "Suppression Characteristics of a 37-Tube Greatrex Model Jet Nozzle With Various Types of Ejector Shrouds," A. Elston, July 25, 1968.

D22 Coordination sheet SST-ANPD-90, "Model-Scale Test of a 3.33 Area Ratio, 37 Plain-Ended-Tube Nozzle (HM-AP-43) With a Close-Fitting Ejector," D. H. Underwood, August 7, 1968.

D23 Coordination sheet SST-ANPD-109, "A Preliminary Acoustic Analysis of a 36-Spoke Area Ratio 2.06 Jet Nozzle's Noise Characteristics (HM-AP-15)," C. P. Wright, September 26, 1968.

D24 G. C. Teeter and J. R. Alberti, *Thirty-Six Spoke Jet Noise Suppressor Acoustic and Performance Test Analysis*, document D6A11501-1, The Boeing Company, March 1969.

D25 Coordination sheet SST-ANPD-132, "A Preliminary Acoustic Analysis of a 37-Tube Area Ratio 3.33 Jet Nozzle's Noise Characteristics (HM-AP-55)," C. P. Wright, November 26, 1968.

D26 Coordination sheet SST-ANPD-198, "General Electric JENOTS Facility 37-Tube (3000°F) Suppressor Nozzle Test Results," C. P. Wright, September 12, 1969.

D27 Coordination sheet SST-ANPD-53, "A Preliminary Acoustic Analysis of a 12-Lobe Greatrex Jet Nozzle Acoustic Noise Characteristics (HM-AP-57)," C. P. Wright, March 26, 1968.

D28 Coordination sheet SST-ANPD-202, "Tube-Spoke Noise Suppression Parameter Study," A. W. Elston and R. B. Tate.

D29 Coordination sheet SST-ANPD-159, "Preliminary Acoustic Report on Model Scale Tests of an Area Ratio 3.1, 16-Tubed Spoke Suppressor, HM-AP-78," D. H. Underwood, February 28, 1969.

D30 Coordination sheet SST-ANPD-150, "A Preliminary Acoustic Analysis of a 126-Tube Area Ratio 3.33 Jet Nozzle's Noise Characteristics (HM-AP-85)," E. A. Wolff and R. B. Tate, March 10, 1969.

D31 Coordination sheet SST-ANPD-185, "Repeatability of the 126-Tube (Area Ratio 3.33) Nozzle Jet Noise Characteristics," R. B. Tate, July 25, 1969.

D32 Coordination sheet SST-ANPD-187, "The Effect of Area Ratio on the Suppression Characteristics of a 126-Tube Nozzle," A. W. Elston, August 26, 1969.

D33 Coordination sheet SST-ANPD-188, "Acoustic Evaluation of a 126-Elliptical Tube (AR = 2.8) Nozzle," R. B. Tate, July 30, 1969.

D34 Coordination sheet SST-ANPD-195, "Preliminary Acoustic Evaluation of the 126-Tube Primary Nozzle With Variable Tube Parameters and an Unlined Shroud," R. B. Tate, August 25, 1969.

D35 Coordination sheet SST-ANPD-200, "Preliminary Acoustic Evaluation of the 126-Tube Primary Nozzle (AR = 3.33) With Variable Unlined Shroud Geometry," R. B. Tate, September 9, 1969.

D36 Coordination sheet SST-ANPD-205, " Tabulated PNL and PNL Suppression Values for the 330-Tube Nozzle Test Series, " J. R. Alberti, October 15, 1969.

D37 Coordination sheet SST-ANPD-14, "Preliminary Results of Recent Noise Suppression Measurements on Model Jet Nozzles, Type MAE 4A, MAE 152, MPP 130-20, MAE 53-18, MAE 203-3 and MPP 452," C. P. Wright, August 1967.

D38 Coordination sheet SST-ANPD-71, "A Comparison of Measurement Methods Used in Evaluating the Noise Suppression Characteristics of the MPP 152 and MPP 452 Model Jet Nozzles," A. Elston, June 24, 1968.

D39 Coordination sheet SST-ANPD-65, "A Preliminary Acoustic Analysis of a 253-Tube (Area Ratio 4) Jet Nozzle's Acoustic Characteristics," C. P. Wright, June 6, 1968.

D40 J. Campbell and E. A. Wolff, *Scale-Model Jet Noise Suppression Program*, T6A11035-1, The Boeing Company, March 1968.

D41 Coordination sheet SST-AN-20-63, "Scale Model Jet Noise Suppression Program. Chute Longitudinal Position and Angle of Attack Studies Report," J. M. Campbell and J. V. O'Keefe, October 26, 1967.

D42 Coordination sheet SST-AN-20-22, "Angle of Attack Study Retest," J. M. Campbell, May 7, 1968.

D43 Coordination sheet SST-ANPD-62, "Jet Noise Suppression Characteristics of a Convergent Primary With a Chuted Ejector," R. B. Tate, May 7, 1968.